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JOURNAL OF PALEONTOLOGY

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VOLUME 18 JANUARY, 1944 NUMBER 1

CRETACEOUS OF THE MESABI IRON RANGE, MINNESOTA

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ABSTRACT—The Cretaceous deposits of the Mesabi district in Minnesota are spread as a mantle over an uneven surface of the upper Huronian iron ore formations and are exposed in the mines from Coleraine to Virginia and Eveleth beneath the Wisconsin drift. The rocks are probably largely of continental origin in the eastern part but grade westward into marine materials. A prevailing basal conglomerate composed of fragments of heavy ferruginous chert and iron ore, paint rock, and porphyry pebbles indicates that it was largely derived from the underlying iron formations and other pre-Cambrian rocks. Locally the materials of the conglomerate are rounded but are for the most part angular indicating short transportation. The coarse conglomerate grades vertically into a somewhat glauconitic fine pebble conglomerate or grit, which in the west end of the district bears marine fossils and grades upwards into a ferruginous grit and sandstone containing an abundant molluscan assemblage. At the Hill Annex mine near Calumet, pockets of blue-green shale occur in the upper part, and this same shale was once extensively exposed around Bovey and Coleraine, Minnesota. All of these sediments are now assigned to a formation termed the Coleraine and on the basis of the invertebrate fauna are considered the age equivalent of the lower Benton in the Colorado series. This invertebrate fauna comprises 60 species and varieties, of which 14 species and at least one variety are described as new.

INTRODUCTION

THE Cretaceous deposits in the Mesabi Range have been known for at least 45 years, but a study of the faunal assemblage was never made. During a 12-month period in 1937 and 1938, the writer studied in detail the Mesabi invertebrate fossil collection at the University of Minnesota and submitted the results to the Graduate School as a thesis problem. The Minnesota collection was started in 1923 by members of the department of Geology, who continued to add to it over a period of several years. Dr. C. R. Stauffer and student assistants obtained the larger portion of the material during the summers of 1928 and 1929. During the latter part of the last decade there was little activity in the iron district, and consequently there were no new exposures of the Cretaceous. Good fossil specimens were difficult to find during the field season of 1937 when the writer visited the region.

The fauna listed and described in this paper has in part been compared with the type specimens of the Colorado series in the United States National Museum, where Dr. J. B. Reeside, Jr., and Dr. L. W. Stephenson of the U. S. Geological Survey kindly aided in many ways. Dr. Reeside later read the manuscript and offered suggestions regarding the determination of some of the species and the correlation of the formation. His criticism has been of great value and has necessitated some revision in the paper originally submitted at the University of Minnesota. The writer also desires to express his

appreciation to Dr. C. R. Stauffer, who helpfully supervised the study at the University of Minnesota, and to the Minnesota State Geological Survey for making the work possible.

Though the Minnesota collection is large and represents a fair-sized faunal assemblage, it cannot be inferred that the invertebrate faunal list of the Mesabi Cretaceous is exhausted by this investigation. The present intensified mining activity and the future operations in the area may expose more Cretaceous sediments that might yield additional fossils. A few unidentified forms may be hidden in old private collections.

No attempt was made to identify any vertebrate material such as shark and reptile teeth and vertebrae, which are rather plentiful. The plant life has likewise been neglected and attention confined to the invertebrates.

Some information was obtained from the 1928 field notes of Dr. C. R. Stauffer and Mr. R. E. Gile, and their sections from the Mesabi area have been used with slight revision of terminology. Many of the sections they measured were obscured by surface slump in later years, and their descriptions are the only record of the exposures.

THE CRETACEOUS SEDIMENTS

The Cretaceous deposits of the Mesabi district in Itasca and Saint Louis counties are spread as a mantle over an uneven surface of the tilted upper Huronian iron ore formations. They are exposed beneath the drift in mines from Coleraine to Virginia and Eveleth and small patches occur as far east as Embarrass Lake. The rocks are probably largely of continental origin in the east but grade westward into marine materials. A prevailing basal conglomerate composed of fragments of heavy ferruginous chert and iron ore, paint rock, and porphyry pebbles indicate that it was largely derived from the underlying iron formations and other pre-Cambrian rocks. The materials of the conglomerate are locally rounded but for the most part are angular, indicating short transportation. The coarse conglomerate grades vertically into a fine pebble conglomerate or grit, which is compact but on exposure tends to disintegrate and to lighten in color. Glauconite occurs in some of it. In the west end of the district, the fine conglomerate bears marine fossils and grades upwards into a ferruginous grit and sandstone containing an abundant molluscan assemblage. At the Hill Annex mine near Calumet, pockets of blue-green shale occur in the upper part. Shale was once extensively exposed in the upper part of the formation around Bovey and Coleraine, Minnesota. Overlying the Cretaceous sediments everywhere is a considerable thickness of Wisconsin drift. In places the drift is directly on the iron formation, indicating a complete removal of the Cretaceous beds by glacial action.

Around Coleraine.—The Cretaceous sediments have been exposed in several pits around Coleraine. Shale containing oyster beds once extended over nearly the entire Hill Walker pit and continued eastward into the western part of the Morrison pit. In the Canisteo pit, near the entrance to the Walker pit, the basal conglomerate bore pebbles of quartz, iron formation, and highly altered igneous and metamorphic rock, all firmly cemented. This graded through a few inches of a red-green, fine pebble conglomerate into a few feet of massive fine lean iron ore. The overlying material was removed prior to survey investigations. A few fish scales were found in the lean ore. In the north cut there were about 20 feet of Cretaceous conglomerates and soft shales.

Abundant shark and reptile teeth and a few vertebrae have been collected by survey members from the dump of lean ore at the screening plant of the Canisteo pit, 1½ miles south of Bovey, Minnesota.

The Cretaceous is no longer exposed in the Morrison mine north of Bovey, Minnesota, but formerly existed in the south end of the pit. About a foot of coarse conglomerate occurred at the base; the pebbles were composed of the underlying iron-ore formation, some being highly polished pieces of hematite and limonite in a greenish iron-clay matrix. Over this conglomerate was about 8 feet of greenish iron-clay with concretions of the same material. No fossils were ever found in the concretions. Along the west side of the pit about 6 inches of fine pebble conglomerate in a green gritty matrix was overlain by 5 to 7 feet of green to red soft fine lean ore. The overlying Cretaceous shale

of the Walker pit area has been removed by erosion or mining operations from the Morrison region. In the eastern part of the pit 3 to 4 feet of hard limy shale bearing poor fossils, were exposed at one time.

Vicinity of Marble and Calumet.—In the northeast corner of the Arcturus mine at Marble the maximum thickness of the Cretaceous encountered during the height of operations was 12 feet. The coarse basal conglomerate about a foot thick was overlain by a fossiliferous grit of lean ore. Most of the Cretaceous is now covered by surface slump. At the Hill Annex mine near Calumet the Cretaceous was not encountered in the north end of the pit where drift is in contact with the iron formation. In the south face of that mine 25 to 28 feet of Cretaceous sediments occur. Ten to 18 feet of coarse basal conglomerate is overlain by 12 to 20 feet of fossiliferous gritty lean ore. In the upper part of the grit are erosion channels filled with green shales making patches 4 to 5 feet thick and containing abundant oyster shells but weathered so that the material is mealy. The upper part of the grit is softer than the remainder and occasionally shows fine laminations. There is a fossiliferous green shale in the upper part of the exposure in the southeast corner of the mine. Carbonized fossil wood is quite abundant toward the west end of the exposure but is scarce where the invertebrates are found. Many bones and teeth recovered from the dump by Dr. Stauffer in 1928, probably came from part of the conglomerate in the south face of the mine.

Near Keewatin.—In the Bennett open-pit mine at Keewatin the basal conglomerate is nearly flat but dips slightly eastward. Large boulders of taconite, porphyry, and polished pebbles of limonite and hematite occur loosely cemented in a white gritty matrix. Many of the boulders are more than 2 feet in diameter. Above the boulder bed is about 25 feet of lean gritty iron ore succeeded by 7½ feet of red shales and capped by 7 feet of coarse conglomerate. The hard layers are fossiliferous, and a great many shark and reptile teeth and vertebrae have been taken from this horizon.

Near Hibbing.—Cretaceous materials occur as irregular fillings in depressions in the eroded surface of the tilted Biwabik iron formation in the Sellers townsite pit at North Hibbing. In places the initial deposit is a coarse rounded-pebble conglomerate with boulders of taconite and porphyry and pieces of quartz and highly polished pebbles and cobbles of hematite and limonite in a light-colored, laminated, gritty matrix. Some of the boulders are over a foot in diameter. Either above the boulder conglomerate or directly on the eroded taconite, is a flat-lying bed of light-colored, fine angular pebble conglomerate. Most of the angular fragments are only an eighth to one-half inch in diameter and are composed of red earthy hematite from the underlying formation. This bed is of variable thickness; as much as 12 feet was exposed in the east face in 1928, while along the south face a thickness of 5 to 20 feet included a thin layer of fine angular hematite-pebble conglomerate, firmly cemented in a cherty green matrix and separating overlying material of the same light-colored conglomerate. Apparently the Cretaceous sediment is of nonmarine origin. No fossils have been reported from the mine.

In the south face of the Sellers pit the Cretaceous is overlain by 30 feet of red drift succeeded by 10 to 30 feet of stratified clay, sand and gravel with 25 feet of gray drift above. In the east face of the pit 16 feet of stratified glacial sands and gravels overlie the Cretaceous and iron formations and in turn are covered by about 35 feet of gray drift with large boulders.

Drill records from the Scranton pit in North Hibbing indicate that the Cretaceous conglomerate was somewhat thicker than 100 feet in the middle of the pit but thinned laterally to about 10 feet on the sides. The Cretaceous sediments apparently were continental fillings of an old erosion channel, with the top beds of flat-lying materials. On the north side of the pit a bench exposed 18 feet of massive and blocky conglomerate containing coarse angular and fine round pebbles cemented by a green cherty matrix. The top 4 feet showed slight bedding.

Near Virginia.—At Virginia the conglomerate occurs in local patches. A hard massive conglomerate 3 to 6 feet in thickness was encountered during operations in the south face of the Alpena pit and in the north side of the Sauntry pit. Some likewise occurred

in the Missabe Mountain pit but was removed during operations. The pebbles of the conglomerate are angular and range from small fragments to pieces a foot in diameter firmly cemented in a red massive cherty matrix. This conglomerate, like that found near Hibbing, may have been deposited as continental material east of the marine beds. Fossils have not been found, and the variation in size and the angularity of rock fragments suggest short transportation.

Cuyuna Range.—The Cuyuna iron-ore district, located in the central part of the state, trends southwesterly from the center of Aitkin County through Crow Wing and Morrison counties, into Todd County. The most important iron-bearing part is in Crow Wing County, and drilling indicates that outliers of probable Cretaceous sediments lie beneath glacial drift of that area. Some of the material is reported (Van Hise and Leith, 1911, p. 215) to be a ferruginous conglomerate and to resemble the conglomerate of the Mesabi Range. Clays associated with the conglomerate may be in part the equivalent of the Cretaceous lignitic and bauxitic clays exposed in Morrison County along the west bank of the Mississippi River near the mouth of Two Rivers, 2 miles east of Bowlus.

In recent years, material that is apparently of Cretaceous age was found in at least five test holes drilled on the Great Northern iron-ore properties west of the Mississippi River in Aitkin and Crow Wing Counties, north of the Cuyuna Range. Gray shale, sandy clay, and sand cuttings and cores suggestive of Cretaceous sediments were obtained beneath 160 to 212 feet of glacial drift. This material has recently been studied by members of the Minnesota Geological Survey, and fish teeth, bone fragments and arenaceous or agglutinated foraminifers have been found in samples from three of the test holes. One test hole (sec. 36, T. 51 N., R. 26 W., Aitkin County) drilled at a location about 23 miles airline north-northeast of the town of Aitkin, penetrated 160 feet of glacial drift, 140 feet of gray to black shale and sandy shale, and 85 feet of sand. Foraminifers, fish teeth and bone fragments are fairly common in the shale cuttings, and the foraminifers are especially abundant in the upper part of the shale. Another hole drilled approximately 18 miles north of Aitkin (SE. part T. 50 N., R. 27 W., Aitkin County) penetrated 160 feet of soft gray sandy shale containing fish teeth, scales, bone fragments, and foraminifers. Several species of foraminifers were present in these cuttings, and the number exceeded that found in samples from other test holes. They have not been specifically determined but are apparently of Cretaceous age.

CRETACEOUS SECTIONS

All measured sections of Cretaceous exposures were taken, with some revision, from field notes by Dr. C. R. Stauffer and R. E. Gile (Field Notebook 11, Minnesota Geol. Survey, 1928).

EXPLANATION OF PLATE 1

All figures natural size.

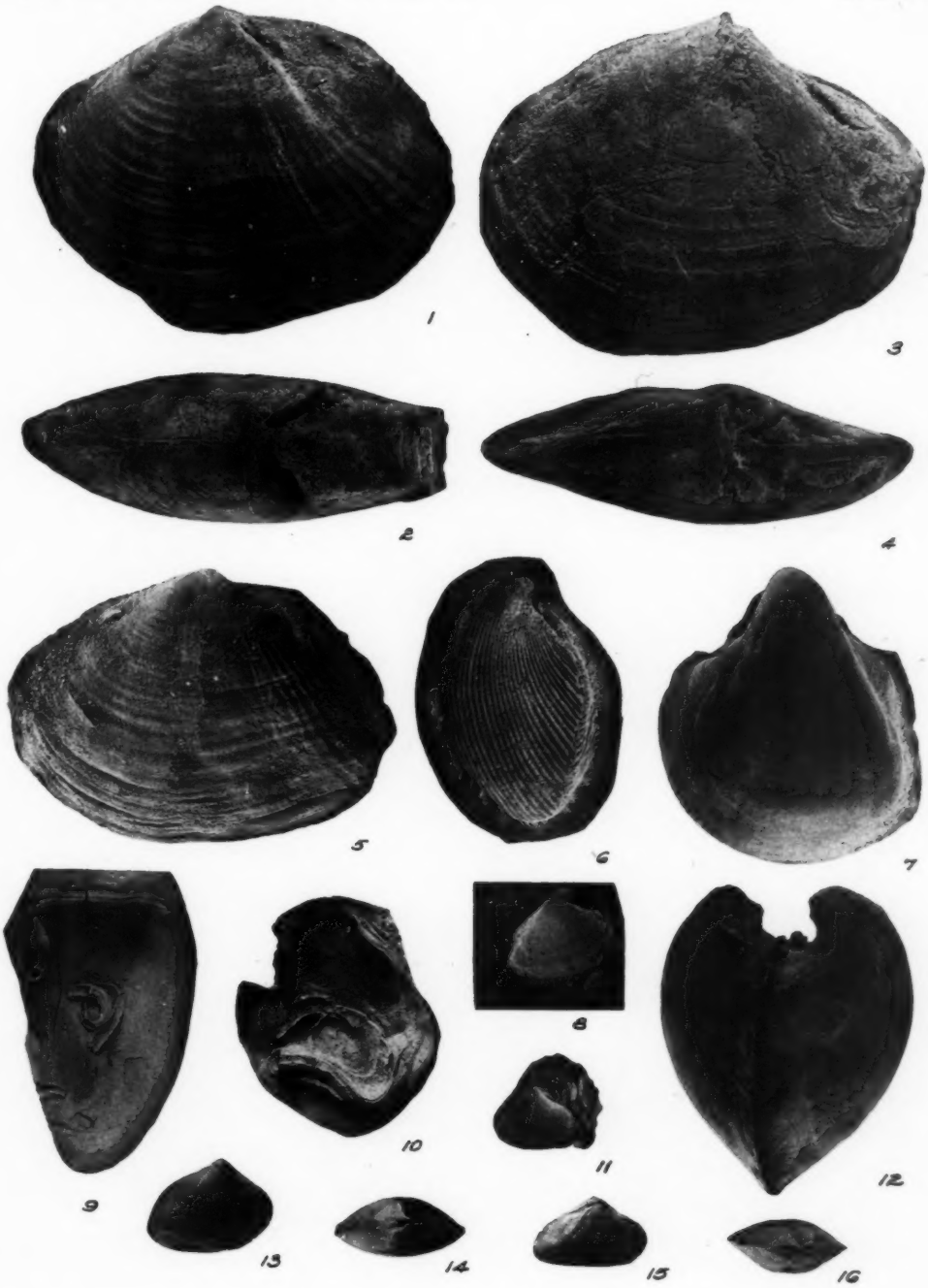
FIGS. *1, 2, 5—Anatimya plicata* Bergquist, n. sp. *1, 2,* Left and dorsal views of internal mold of a large cotype. *5,* Left view of a small cotype. Both specimens from conglomerate of Coleraine formation, Arcturus mine, Marble, Minn. (p. 21)

3, 4—Anatina marblensis Bergquist, n. sp. Left and dorsal views of a large cotype. Internal mold from conglomerate of Coleraine formation, Arcturus mine, Marble, Minn. (p. 21)

6, 7, 12—Cardium enstromi Bergquist, n. sp. *6,* Squeeze of an external mold (from holotype); impression of spines could not be obtained. *7, 12,* Left and posterior views of holotype, an internal mold. Conglomerate of Coleraine formation, Hill Annex mine, Calumet, Minn. (p. 22)

9, 10—Serpula bicarinata Bergquist, n. sp. Tubes attached to fragments of *Ostrea gilei* n. sp. Bryozoa also attached to shell in *9.* Coleraine formation, Arcturus mine, Marble, Minnesota. (p. 10)

8, 11, 13–16—Cymbophora utahensis (Meek)? *8, 11,* Two right valves (internal molds) in situ; Coleraine formation at Coleraine, Minn. *13, 14,* Right and dorsal views of small internal mold. *15, 16,* Right and dorsal views of a small internal mold. Conglomerate of Coleraine formation, Arcturus mine, Marble, Minn. (p. 24)



Bergquist, Cretaceous Fossils

Bergquist, Cretaceous Fossils

Exposure July 15, 1928 in south face of Sellers Townsite mine, North Hibbing

	Feet
Pleistocene:	
12. Drift, gray boulder hardpan; many large boulders of granite and gabbro	25
11. Clay, gravel and sand; stratified aqueo-glacial clay at base, bedded gravel and sand above	10–30
10. Drift, red hardpan; boulders numerous though not large, mostly under 1 foot in diameter	30
Cretaceous (Colorado series), Coleraine formation:	
9. Conglomerate; fine hematite pebbles in white matrix	2– 4
8. Conglomerate, massive; fine angular hematite pebbles in green matrix	1– 5
7. Conglomerate; fine angular red hematite pebbles ⅛ to ½ inch diameter in white matrix; beds flat lying	5–20
Pre-Cambrian; Biwabik formation:	
6. Slaty hematite and limonite; some massive blue cherty layers; surface irregular	15–27
5. Iron ore, slaty red and yellow; cherty in part	7.2
4. Limonite, yellow cherty; some black hard, partly earthy hematite bands	29.2
3. Hematite, cherty; mostly red and blue; some sandy taconite and limonite bands	23.3
2. Limonite; mostly earthy, stratified with hard cherty layers	7.7
1. Hematite, massive powdery blue.	4

Exposure July 15, 1928 on east side of Sellers pit, North Hibbing

	Feet
Pleistocene:	
10. Drift, boulder-bearing gray hardpan	34
9. Sand and gravel, aqueo-glacial	16.4
Cretaceous (Colorado series), Coleraine formation:	
8. Conglomerate; red angular unpolished pebbles of ⅛ inch to 1 inch diameter, minor pebbles of taconite, in white matrix	12
Pre-Cambrian; Biwabik formation:	
7. Limonite, massive cherty brown and yellow	22.3
6. Concealed	8
5. Taconite, massive blocky; slaty bands	11.2
4. Concealed	10.3
3. Taconite, altered slaty and powdery; contains some brown and red iron ore with layers of white sandy taconite	24
2. Concealed	5
1. Hematite, massive cherty blue and red; contains gritty altered taconite layers and 2- to 4-inch bands of hard cherty blue iron ore	37.5
Level of water in middle of pit.	

Exposure July 24, 1928 in north face of Bennett open pit, Keewatin

	Feet
Pleistocene:	
15. Drift, gray hardpan; contains boulders which average 1 foot in diameter	25–40
Cretaceous (Colorado series), Coleraine formation:	
14. Conglomerate, coarse brown; composed of polished pebbles of hematite and limonite, and pebbles of taconite and slaty iron formation	7
13. Shale, rudely laminated dark greenish-red	7.4
12. Iron ore, fine-grained to gritty massive reddish	10
11. Iron ore, finely granular lean gritty; streaks of red and yellow clay	6– 7
10. Conglomerate; fine pebbles in green matrix	0.5
9. Iron ore, lean massive greenish-red; contains many tiny pebbles.	6
8. Limonite, concretionary	0.4
7. Iron ore, massive fine-grained to earthy; streaks of ochre; few small pebbles at base	2
6. Conglomerate, coarse basal; pebbles of polished hematite and limonite and of taconite, porphyry and quartz	2.3
Pre-Cambrian, Biwabik formation:	
5. Limonite, slaty yellow; some hematite bands	19.2
4. Hematite, red slaty thinly laminated; contains a few layers of earthy limonite and thin layers of hard cherty blue hematite	25

EXPLANATION OF PLATE 2

All figures natural size except *1* and *2*.

FIGS. *1–8*—*Exogyra lamellosa* Bergquist, n. sp. Cotypes. *1*, *2*, Opposite views of a large left valve, ×⅔; surface view shows irregularities and attachment to a small right valve of another of the same species. *3*, View of a left valve with high ligament area, beak and umbonal region corroded. *4*, *5*, Opposite views of a left valve, posterior portion broken, surface irregular and shows sponge borings. *6*, *7*, Opposite views of a medium-sized right valve. *8*, Internal view of a small left valve attached to a right valve of same species. All specimens from shales of Coleraine formation, Arcturus mine, Marble, Minn. (p. 17)

	Feet
3. Hematite, massive and bedded cherty blue-red; some botryoidal limonite, black on surface	24.2
2. Concealed. Beds dip steeply down toward middle of pit	11.4
1. Hematite, slaty	4
Level of water in middle of mine.	

Exposure July 24, 1928 near east end of north face of Bennett open pit, Keewatin

	Feet
Cretaceous (Colorado series), Coleraine formation:	
11. Conglomerate and intercalated gray and yellow clay, possibly not in place	5.5
10. Conglomerate, fine; soft clay limonite matrix	0.7
9. Iron ore, lean rudely laminated clayey; red and yellow clay streaks; gritty red-brown clay at top	1.4
8. Iron ore, gritty dark to almost black; limonitic clay streaks at all angles; rudely laminated near top	5.5
7. Concealed by thick surface slump; contains pebbles, some of highly polished hematite and limonite	12
6. Iron ore, fine-grained greenish lean; red hematite streaks in all directions; a few scattered small pebbles	6.5
5. Conglomerate, fine pebble; matrix like that of bed 6	0.4
4. Iron ore, massive somewhat gritty greenish-maroon; contains fine pebbles	5.9
3. Limonite, soft earthy; contains hard concretions	0.3
2. Iron ore, fine-grained earthy maroon; streaks of yellow and red ochre; bed is rudely laminated	2
1. Conglomerate, coarse pebble; contains large rounded boulders of taconite, paint rock and large and small polished pebbles of limonite and hematite in a light-colored gritty matrix	2.5
Top of Biwabik Formation.	

Exposure July 18, 1928 in west side of northeast cut of Canisteo mine, Coleraine

	Feet
Pleistocene:	
11. Drift, gray; boulders mostly dark schist, some granite of various sizes, many over 2 feet in diameter	25–40
Cretaceous (Colorado series), Coleraine formation:	
10. Shale, soft massive green-red; contains small rounded polished pebbles of hematite and limonite.	4–10
9. Shale-conglomerate, green-red; somewhat hardened	2.2
8. Shale, soft massive gritty greenish-red; contains very few pebbles	3
7. Conglomerate, coarse; pebbles of taconite and hematite, and of polished limonite and hematite	1.2
Pre-Cambrian, Biwabik formation:	
6. Limonite, cherty bedded; in thin strata intercalated with cherty bands; some hematite	16.5
5. Taconite, massive	2.8
4. Limonite, earthy; 1-inch strata separated by ½-inch hard cherty bands	4.8
3. Taconite, massive blocky dark banded	4.7
2. Hematite, hard cherty red and blue; in massive layers of 1 to 2 inches separated by porous dark sandy taconite	18.2
1. Concealed to flooded water level in pit	7.7

Exposure July 18, 1928 in Canisteo pit near entrance to Walker pit, Coleraine

	Feet
Cretaceous (Colorado series), Coleraine formation:	
7. Iron ore, shaly brownish lean; laminae prominent on weathered surface	1.7
6. Iron ore, massive blocky fine-grained green to red; almost black in patches; contains questionable fish scales	2
5. Concretionary layer; concretions black	0.2
4. Iron ore, soft massive fine-grained red-green lean; questionable fish scales and one tooth noted	1.4
3. Conglomerate, hard massive fine hematite pebble; green-red matrix	0.4
2. Conglomerate; pebbles up to about 2½ inches in diameter, of quartz, iron formation and highly altered igneous and metamorphic rock, all firmly cemented	1.3
Pre-Cambrian, Biwabik formation:	
1. Taconite	6.8

Exposure August 8, 1928 in Arcturus mine, Marble, Minnesota, from lowest point in east end of pit to top of drift on north side of mine near east end

	Feet
Pleistocene:	
9. Drift, gray; pebbles of light and dark igneous and metamorphic rock	30–40
8. Drift, red hardpan; boulders of taconite, slate, and igneous rocks	5–15
Cretaceous (Colorado series), Coleraine formation:	
7. Conglomerate, clayey gray-brown; polished pebbles of hematite and limonite. No fossils	5.2

	Feet
6. Concealed. Top of bench (fossiliferous shale)	5
5. Iron ore, lean clayey gray; contains oyster shells	7.2
4. Conglomerate, hard fine; polished limonite and hematite pebbles; yellow limonitic clay matrix	0.7
3. Conglomerate, coarse basal; pebbles of iron formation and taconite	1.2
Pre-Cambrian, Biwabik formation (surface irregular unconformity):	
2. Iron ore, thinly layered cherty blue; intercalated with weathered sandy taconite in 2- to 3-inch beds	26–35
1. Iron ore, massive dark-blue to black cherty; some rudely bedded, breaking into cuboid pieces. Taconite found at 30 feet but apparently local. Level of water in east end of pit.	37.7

Stauffer's notebook contains the following notations on the above section:

There is an erosion remnant of taconite in the east end of the north side of the mine which separates the portions of the Cretaceous. On the west side of this remnant the material is a brownish-gray polished ore pebble conglomerate with no fossils (beds 6 and 7). East of this taconite the Cretaceous is somewhat thicker, the base is at least 18 feet below the top of the taconite remnant, the top of which is even with the top of bed 7. The material east of the remnant is as shown in the section below. These two beds take the place of 6 and 7 above.

Drift	35–55
7. Conglomerate, coarse; pebbles of polished ore and taconite, some up to 6 inches in diameter	2.3
6. Iron ore, variable gray-green clayey; more clay at base, more gritty at top; abundant polished pebbles of limonite and hematite; contains oyster and other pelecypod shells	10.5–15.2

A bed of Cretaceous conglomerate (polished hematite and limonite pebbles) is found about 15 feet higher than that shown as the top of the section. Taconite is also found higher than the top of the Cretaceous. Both the surface of the taconite and Cretaceous are irregular.

Exposure July 13, 1928 in south face of Hill Annex mine (NW. ¼ sec. 16, T. 56 N., R. 23 W., Itasca County), Calumet
(Stauffer and Thiel, 1941, p. 105.)

	Feet
Pleistocene:	
12. Drift, sands, gravels, and boulder beds	125
Cretaceous (Colorado series), Coleraine formation:	
11. Iron ore, redeposited, red and gray, soft, massive, with fine pebbles. Fossils common	9
10. Conglomerate, red pebbles in a gray matrix	6.3
9. Iron ore, redeposited, red to gray, gritty, with fragments of wood at some places. At other places this same horizon carries an abundant molluscan fauna	3
8. Conglomerate, coarse, pebbly, unassorted	0.5
7. Iron ore, redeposited, green, gritty, with occasional pebbles of chert and iron formation	4
6. Conglomerate, gray, coarse pebbles cemented by a green iron sand	0.7
5. Conglomerate, very coarse, with polished black pebbles, chert, taconite, paint rock, hematite, slate, quartz, and other pebbles and cobbles up to 8 inches in diameter	8.2
Pre-Cambrian, Biwabik formation:	
4. Paint rock and slaty red taconite with white bands	8
3. Iron ore, deep red, cherty, gritty, with altered taconite	16
2. Iron ore, laminated, blue, cherty, with sandy beds and unaltered taconite	20
1. Iron ore, blue, hard, massive, cherty, laminated to bottom	28

Exposure August 10, 1928 in south face of Hill Annex mine, near east end of pit, Calumet

	Feet
Pleistocene:	
11. Drift, gray hardpan; upper portion contains large boulders of fresh granite, syenite, and gabbro; lower portion largely of fine water-lain stratified sand and gravel with local blue-gray clays	88
Cretaceous (Colorado series), Coleraine formation:	
10. Iron ore, gritty fine-grained greenish-red; contains rounded hematite pebbles	6.2
9. Conglomerate; rounded 1-inch pebbles in red-green cement	0.7
8. Iron ore, fine-grained green to red gritty lean; locally bluish in color	5.2
7. Conglomerate, coarse; contains large rounded pebbles of fresh and altered taconite, hematite, porphyry, paint rock, slate, quartz, in order of abundance	18
Pre-Cambrian, Biwabik formation:	
6. Taconite (paint rock), thinly laminated slaty; banded red and white	8

	Feet
5. Iron ore and taconite, thinly stratified. Iron ore composed of deep-red cherty layers. Taconite mostly white, granular to gritty.	16
4. Concealed (bench)	3.5
3. Iron ore, cherty blue; laminated with sandy and massive unaltered taconite. Color of soft material variegated	17
2. Concealed (bench)	3.6
1. Iron ore, massive hard cherty blue; in laminae 2 to 3 inches in thickness; some bands porous; ore breaks in rectangular blocks.... Level of water in deepest cut in east end of mine.	25.2

COLERAINE FORMATION

Although poorly represented at present, an extensive deposit of Cretaceous shale was once conspicuous in the mines near Coleraine, Minnesota, and in 1929 Dr. C. R. Stauffer applied the tentative field name "Coleraine shale" to it. The section in the Canisteo-Walker pits near Coleraine was regarded as the type. Subsequent mining, however, has removed much of the Cretaceous, and the sections herewith presented probably show but a remnant of the original exposure. From the study of the faunal assemblage, the formation appears to belong to the lower Benton, although a few long-ranging species are comparable to forms of the later Cretaceous. The name Coleraine formation as used in this paper includes all the Cretaceous conglomerates of the Mesabi Range as well as the shales. The formation is probably more than 100 feet thick. The shales occur only in the upper portion of the Cretaceous sediments in the western part of the area; the conglomerate exposures seem to be more extensive and are only the representative of the formation in the eastern part.

The sediments of the Coleraine formation were classed as belonging to the Colorado series by C. A. White (1893). He listed a few genera and suggested that some fossils represented new species. Later, some fragmentary fossils were submitted to T. W. Stanton, who pronounced them "not older than the Fort Benton and probably not younger than the Fort Pierre" (Leith, 1903, pp. 190–191). Dr. Stanton listed five genera and on the basis of a possible *Inoceramus fragilis* Hall and Meek suggested a horizon in the Fort Benton. Most of the forms suggested by White and Stanton are recognized in this study. White, however, classified part of the inner whorls of an ammonoid as *Placenticeras* sp., probably related to *P. lenticulare* Owen, now the genotype species of *Sphenodiscus*. This genus does not occur in the University collection, and it is doubtful if it is to be found in the formation. *Epengonoceras* cf. *dumblei* (Cragin) is present, and it may have been a fragment of an ammonoid of this genus that was submitted to Dr. White.

THE COLERAINE FAUNA

The Cretaceous invertebrates of the Mesabi Range are dominantly Mollusca. The pelecypods comprise the largest group and are represented by 28 genera and 39 species, of which 11 are new. Three varieties, one at least new, are recognized. The Ostreas and Exogyras are particularly abundant, especially in the shales of the region. Six species of *Ostrea* and five of *Exogyra* comprise the oyster assemblage. Ten or 11 genera and 12 species of gastropods occur in the conglomerate. Three species of gastropods are new. Four genera of cephalopods and one scaphopod make up the remaining Mollusca. Other forms are as follows: one new species of Annelida, one unidentified encrusting bryozoan and one long-ranging linguloid brachiopod. Members of the Anthozoa and Echinoidea are entirely lacking, probably because of an unfavorable environment. Foraminifers may be present, but none were encountered in examinations of the sediments. Fragments of several species of arthropods are found in some of the conglomerates.

A great many shark and other fish teeth, together with a few reptile teeth and fish vertebrae have been collected in the vicinity of Calumet and Coleraine, and occasional specimens occur elsewhere. Some fish scales are encountered in the shales of the Hill Annex mine. Most of them are small, but an occasional scale is about three-fourths inch in diameter. Parts of reptile skeletons also have been found at the Hill Annex in the conglomerate.

FLORA

A considerable amount of carbonized wood in the form of twigs, branches, and

even parts of logs is scattered through the conglomerate in the western Mesabi area, especially in the Hill Annex mine. Some specimens of the wood have been pyritized and are entirely filled with *Teredolites*. The wood has not been identified, but it represents both coniferous trees and members of the dicotyledons, for impressions of cones, needles, and leaves and one seed have been found in the conglomerate, and a few leaf impressions occur in the shales. Fossil wood is unknown in the eastern portion of the range near Virginia and Hibbing.

CORRELATION OF THE FAUNA

Most of the fossils identified in the Coleraine formation are forms that range throughout the Colorado series, and some extend into the late Cretaceous beds. A few others are the same as forms either originally described from basal Colorado beds or that have been found mostly in the earliest sediments of that series. Among these are the following:

Barbatia micronema (Meek)
Corbula kanabensis Stanton
Cymbophora utahensis (Meek)
Nucula coloradoensis Stanton
Ostrea prudentia White
Parapholas sphenoideus White
Pecten (*Camptonectes*) *platessus* (White)
Aporrhais (*Lispodesthes*) *nuptialis* (White)

None of the above, however, are of much value in fixing the age of the sediments.

Ammonoids are meagerly represented in the Minnesota sediments, and the specimens are too incomplete to permit definite specific determinations; but the few that are present in the fauna are characteristic and indicate an early Upper Cretaceous age. The genera *Acanthoceras*, *Epengonoceras*, and *Metacalycoceras* all belong to the earliest Cretaceous. These are identified in the Mesabi fauna. *Metoicoceras swallovi* (Shumard) also indicates a very early Upper Cretaceous horizon, though the Minnesota form appears to be a variety of that species. The suturing on this variety is more complete than on *M. swallovi puercoensis* Herrick and Johnson, a form which may belong in the middle of the Benton. On the basis of the apparent early upper Cretaceous age of the ammonoids, the Coleraine formation can be assigned to the lower Benton of the Colorado series.

FAUNA OF THE COLERAINE FORMATION

	Hill Annex mine	Arcturus mine	Coleraine-Bovey
Annelida.			
Serpula bicarinata, n. sp.	×		×
Bryozoa (encrusting form).		×	
Brachiopoda (Inarticulata).			
Lingula subspatulata Hall and Meek?	×		
Mollusca, Pelecypoda.			
Nucula coloradoensis Stanton	×		
Yoldia calumetensis, n. sp.	×		
Barbatia micronema (Meek)	×	×	
Pinna sp.	×		
Gervillia propleura Stanton?	×		×
Inoceramus fragilis Hall and Meek	×	×	×
Inoceramus fragilis mesabiensis, n. var.	×		
Pteria gastrodes (Meek)	×	×	
Volsella sp.		×	
Ostrea congesta Conrad	×	×	×
Ostrea gilei, n. sp.	×	×	×
Ostrea prudentia White	×	×	×
Ostrea soleniscus Meek, var.		×	
Ostrea (*Alectryonia*) *staufferi*, n. sp.	×	×	×
Ostrea sp.	×		
Exogyra boveyensis, n. sp.	×		×
Exogyra lamellosa, n. sp.	×	×	×
Exogyra mesabiensis, n. sp.	×		×
Exogyra suborbiculata Lamarck	×	×	×
Exogyra sp.		×	
Pecten (*Camptonectes*) *platessus* (White)	×	×	
Pecten (*Camptonectes*) *platessus* (White), var.?	×	×	
Lima utahensis Stanton	×		
Anomia propatoris White	×		
Brachidontes arcturusensis, n. sp.	×	×	×
Pholadomya coloradoensis Stanton	×		×
Anatina marblensis, n. sp.		×	
Anatimya plicata, n. sp.		×	
Etea? sp.	×	×	
Cardium enstromi, n. sp.	×	×	
Legumen cf. *planulatum* (Conrad)	×	×	
Tapes cyprimeriformis Stanton	×	×	
Tapes sp.	×		
Tellina calumetensis, n. sp.	×		
Leptosolen biplicatus Conrad	×		
Siliqua huerfanensis Stanton		×	
Cymbophora emmonsi (Meek)?	×		
Cymbophora utahensis (Meek)?		×	×
Corbula kanabensis Stanton	×		
Parapholas sphenoideus White	×		
Teredolites? sp.	×		
Mollusca, Gastropoda.			
Calliomphalus? colerainensis, n. sp.	×	×	
Nerita? minnesotensis, n. sp.	×	×	

	Hill Annex mine	Arcturus mine	Coleraine-Bovey
Epitonium sp.	×		
Polinices (*Lunatia*) *concinna* (Hall and Meek)	×		
Gyrodes conradi Meek	×	×	
Aporrhais (*Lispodesthes*) *nuptialis* (White)	×		
Aporrhais? sp.	×	×	
Anchura grouti, n. sp.	×	×	
Fusus shumardi Hall and Meek	×		
Volutoderma (*Rostellinda*) *dalli* Stanton	×		
Actaeon propinquus Stanton	×		
Gastropod sp.	×	×	
Mollusca, Scaphopoda.			
Dentalium sp.	×		
Mollusca, Cephalopoda, Ammonoidea			
Metacalycoceras? sp.	×		
Acanthoceras sp.	×		
Metoicoceras aff. *swallovi* (Shumard)	×	×	×
Epengonoceras cf. *dumblei* (Cragin)	×		×
Arthropoda			
Crustacean fragments	×		×
Chordata			
Shark and other fish teeth	×		×
Fish scales and vertebrae	×		
Reptile teeth	×		×

DESCRIPTION OF SPECIES

ANNELIDA

SERPULA BICARINATA Bergquist, n. sp.

Plate 1, figures 9, 10

Tubes small, in groups or alone, looped or irregularly sinuous, increasing gradually in diameter; attached throughout entire length on one side to inner surface of shells of *Ostrea* and *Exogyra;* tube wall thickened and flared along area of attachment; external surface marked by transverse growth lines, two sharp longitudinal carinae continued on upper surface throughout entire length; internal surface smooth. These tubes attain lengths of 30 millimeters or more and a diameter as great as 3 mm. at large end.

This form differs from *S. tenuicarinata* Meek and Hayden in having the external surface marked by conspicuous growth lines and two sharp carinae on the upper surface.

Occurrence: In the conglomerate of the Coleraine formation, Hill Annex mine, Calumet, Minn., and in the mines at Coleraine, Minn.

Cotypes: Cat. No. 5000, Geol. Museum, Dept. of Geology, University of Minnesota.

BRACHIOPODA (INARTICULATA)

LINGULA SUBSPATULATA Hall and Meek?

Lingula subspatulata HALL and MEEK, 1856, Am. Acad. Arts and Sci. Mem., n. ser., vol. 5, p. 380, pl. 1, figs. 2a–b.

A few fragmentary shells may belong to this species. They are embedded in the sandstone matrix of a piece of conglomerate of the Coleraine formation in the Hill Annex mine, and the outline of the shell is not clearly defined.

MOLLUSCA

PELECYPODA

NUCULA COLORADOENSIS Stanton

Nucula coloradoensis STANTON, 1893, U. S. Geol. Survey Bull. 106, p. 94, pl. 21, fig. 9.

A few small molds of separate valves check with Stanton's description as to size and general form. Some of the shell is preserved indicating the concentric lines and striated surface. The crenulated basal margin is reflected on the molds. Denticles can be seen, but the number cannot be determined. These molds closely resemble small forms of *N. cancellata* Meek and Hayden of the Pierre formation, but it is more probable that they belong with Stanton's species.

Occurrence: In the green shales of the Coleraine formation, southeast corner of Hill Annex mine, Calumet, Minn.

YOLDIA CALUMETENSIS Bergquist, n. sp.

Plate 10, figures 2, 5, 8, 9

Shell transversely elongate, greatest dorsally; very inequilateral; slightly convex; umbones low; beaks orthogyrate, slightly anterior. Dorsal margin sloping gently from beaks, anterior margin abruptly rounded above and continued below in a broad curve into the gently arcuate ventral margin; posterior margin ascends obliquely to truncated distal posterodorsal margin. Surface marked by fine concentric growth lines; teeth fine, unequal in size, V-shaped, directed toward beaks, greater number posteriorly, there being about 18 to 22 anteriorly and 25 to 29 posteriorly. Pallial sinus and adductor scars unknown. Largest specimen measures 10 mm. in height and 22 mm. along dorsal margin.

The form bears its closest resemblance to *Y. evansi* Meek and Hayden of the upper Pierre beds and the Fox Hills sandstone, and of the Cannonball member of the Lance formation.

Occurrence: In the shale horizon of the Coleraine formation, southeast corner of Hill Annex mine, Calumet, Minn.

Cotypes: Internal mold of a right valve retaining some of the shell and an internal mold of a right valve showing the teeth; also several other separate valves represented by internal molds; Cat. No. 5044, Geol. Museum, Dept. of Geology, University of Minnesota.

BARBATIA MICRONEMA (Meek)

Trapezium micronema MEEK, 1873, U. S. Geol. Survey Terr. Rept. for 1872, p. 493.
Trapezium micronema, WHITE, 1879, idem, Rept. for 1877, p. 293, pl. 10, fig. 5.
Barbatia micronema, STANTON, 1893, U. S. Geol. Survey Bull. 106, p. 89, pl. 21, figs. 1–4.

A few small internal and external molds representing both right and left valves of this species occur in the shale beds at Calumet. A little thin, chalky shell substance remains on some, and partial imprints of the teeth are preserved on a few specimens. The surface markings are fairly well retained.

In the ferruginous sandstone at Marble, a number of larger internal molds (as much as 5 cm. in length) were found. These are poorly preserved but usually have both valves attached along the hinge area, although the valves are opened. Imprints of the teeth are sometimes partly preserved. Some specimens show a marked invagination about midlength of the ventral margin, the posterior end of the valves being greatly enlarged, and almost twice the height of the anterior portion. Surface markings are poorly indicated.

Occurrence: In the green shale of the Coleraine formation in southeast corner of Hill Annex mine, Calumet, Minn. and in ferruginous sandstone of same formation in northeast corner of Arcturus mine, Marble, Minn.

PINNA sp.

A broken internal mold of the anterior part of a *Pinna* measures 70 mm. in length. Outline of mold appears to be oval. The dorsal line is straight; ventral margin slopes sharply at beak for about 5 mm. and then less abruptly (about 45°) giving a gradually expanding shell, which at the break is about 38 mm. in diameter. There is some suggestion of the beginning of a median fold. Dorsal portion marked by a number of radiating ridges; growth lines subparallel to ventral margin occur on ventral area. This may be a piece of *P. petrina* White.

Occurrence: In the ferruginous conglomerate of the Coleraine formation, south face of Hill Annex mine, Calumet, Minn.

GERVILLIA PROPLEURA (Meek)?

Plate 10, figures 6, 7

Avicula (*Pseudoptera*) *propleura* MEEK, 1873, U. S. Geol. Sur. Terr. Rept. for 1872, p. 489.
Pteria (*Pseudoptera*) *propleura*, WHITE, 1879, idem, Rept. for 1877, p. 281, pl. 10, figs. 2a–c.
Gervillia propleura, STANTON, 1893, U. S. Geol. Survey Bull. 106, p. 74, pl. 10, figs. 1–3.

An internal mold that appears to belong to this species shows the following characteristics. Shell very oblique, inequivalve; left valve very convex, greatest along umbonal region; umbonal ridge rounded abruptly to anterior margin but sloping more gently to dorsal and posterior areas; beak of left valve situated about 10 mm. from anterior end, directed anteriorly, undercut by a V-shaped notch, which separates it from wing so that it projects as a sharp point away from hinge area but not above it. Right valve almost flat, umbonal ridge scarcely defined but bordered by a groove along anterior margin of mold; beak inconspicuous. Hinge line straight, deflected upwards slightly along anterior wing. Anterior margin of mold slopes posteriorly at 45° angle, curving in ventral area into posterior margin, which is probably indented below posterior wing. Anterior wing laterally compressed but not defined from body by any distinct furrow. Posterior wing broken. Surface of left valve marked by strong, widely spaced, radiating plications crossed by growth lines, only the growth lines occur on anterior wing. Sculpturing not retained on right valve.

Figured specimen measures about 68 mm. along umbonal slope and at least 50 mm. along hinge line; maximum height measured normal to hinge on posterior portion is 45 mm.

Occurrence: In the congomerate of the Coleraine formation, Hill Annex mine, Calumet, Minn., and at Coleraine, Minn.

Figured specimen, a nearly complete internal mold: Cat. No. 5038, Geol. Museum, Dept. of Geology, University of Minnesota.

INOCERAMUS FRAGILIS Hall and Meek

Inoceramus fragilis HALL and MEEK, 1856, Am. Acad. Arts and Sci. Mem., n. s. vol. 5, p. 388, pl. 2, figs. 6a–b.
Inoceramus fragilis, WHITE, 1876, U. S. Geol. and Geol. Sur. W. 100th Mer. Rept., vol. 4, p. 178, pl. 15, fig. 3.
Inoceraous fragilis, MEEK, 1876, U. S. Geol. Sur.. Terr. vol. 9, p. 42, text figs. 1, 2; pl. 5, fig. 5.
Inoceramus fragilis, STANTON, 1893, U. S. Geol. Survey Bull. 106, p. 76, pl. 11, figs. 1–5.

A number of internal molds are identical with the typical small form of *I. fragilis* Hall and Meek. Most of these are left valves; a few of the molds show part of the shell material.

Occurrence: In the shales and conglomerate of the Coleraine formation, Hill Annex mine, Calumet, Minn.; the Arcturus mine, Marble, Minn., and from mines around Coleraine, Minn.

INOCERAMUS FRAGILIS MESABIENSIS Bergquist, n. var.

Plate 5, figures 3–6, 8

Internal molds; large forms show a great convexity of the valves; the left valve higher and more convex than right. Beaks strongly incurved and directed forward to terminal position; right beak rising slightly above straight hinge line; left beak much higher than right one, rising as much as 11 mm. above hinge area and overhanging it. Anterior margin straight to gently curved, joining hinge line at about an 80° angle; ventral margin varies from semicircular on broadly rounded specimens to very gently curved on narrow forms having anterior and posterior sides flattened. (On one specimen the anterior margin extends downwards much farther than the posterior one.) Posterior margin straight or flaring outward near hinge line producing a slight winglike extension. Surface marked by fine growth lines and by strong concentric, rounded to angular ridges. Many specimens show fine irregular plications radiating from umbos over convex surfaces of valves.

Dimensions of specimens: Cotype 5019a: height 45 mm.; length at ventral margin, 33 mm.; length at hinge line about 18 mm.; maximum convexity, 36 mm. (left valve 22 mm., right valve 15 mm.). Cotype 5019b: height, 30 mm.; length, 17 mm.; length along hinge, 11 mm.; maximum convexity, 22 mm. Cotype 5019c: height, 55 mm.; length, 30 mm.; length along hinge, 18 mm.; maximum convexity, 35 mm.

The Minnesota variety differs greatly from the typical species and from *I. howelli* White, which Stanton considered as a varietal form. The shell material is not preserved on any of the specimens.

Occurrence: In the conglomerate of the Coleraine formation, Hill Annex mine, Calumet, Minn.

Cotypes: Cat. No. 5019a, 5019b, 5019c, internal molds and several other internal molds (5019); Geol. Museum, Dept. of Geology, University of Minnesota.

EXPLANATION OF PLATE 3

All figures natural size except *11*.

FIGS. *1–5*, *10*, *11*, *20*—*Exogyra lamellosa* Bergquist, n. sp. Cotypes. *1–4*, Opposite views of small right valves. *5*, Right valve showing prominent lamellae and pits by boring sponges. *10*, View of a right valve with considerable convexity. *11*, Large right valve of senile individual, $\times\frac{1}{4}$, showing sponge borings and corrosion; lamellae not very pronounced. *20*, Right valve with sharp lamellae. All specimens from shale of Coleraine formation, Arcturus mine, Marble, Minn. (p. 17)

6–9, *12–19*—*Exogyra mesabiensis* Bergquist, n. sp. Cotypes. *6*, *8*, *12*, *17*, Internal views of small left valves showing high ligament area with extended umbonal region above. *7*, *9*, *18*, Surface views of left valves figured in *6*, *8*, *17*, respectively, showing large attachment scars and irregularity of surface. *13*, Anterior view of small left valve. *14–16*, Surface views of large right valves showing laminations, sponge borings; a small left valve attached to specimen figured in *14*. *19*, Internal view of right valve figured in *16*. All specimens from shale of Coleraine formation, Bovey, Minn. (p. 17)

Bergquist, Cretaceous Fossils

Bergquist, Cretaceous Fossils

PTERIA GASTRODES (Meek)

Avicula (Oxytoma?) gastrodes MEEK, 1873, U. S. Geol. Survey. Terr. Rept. for 1872, p. 491.
Pteria (Oxytoma?) gastrodes, WHITE, 1879, idem. Rept. for 1877, p. 280, pl. 10, fig. 1a.
Avicula gastrodes, STANTON, 1893, U. S. Geol. Survey Bull. 106, p. 72, pl. 9, figs. 7–10.

A number of internal molds of this species were found. Right and left valves occur, either separate or joined but none complete, all having suffered some degree of crushing or distortion. As the wings and ventral region of the shells are incomplete, the outline of the large individuals is not known though it is indicated by the general shape. Most of the molds are more robust than Meek's specimens, resembling *P. salinensis* White of the upper beds of the Comanchean of Kansas in this respect. The left valve shows the greater convexity. The beaks are prominent, tending to be somewhat oblique or nearly vertical with axis of shell. The umbonal area slopes abruptly to the anterodorsal regions; the slope to posterodorsal region is gentle, flattening out along marginal area. Shells as high as 65 mm. are indicated by the molds. Little of the shell substance is preserved, but apparently surfaces were smooth or showed growth lines in part.

Occurrence: In the conglomerate of the Coleraine formation in mines at Coleraine, the Arcturus mine at Marble and in the Hill Annex mine at Calumet. A few small specimens preserving the general outline and some of the shell were found in the green shale of the same formation in the southeast corner of the Hill Annex mine.

VOLSELLA sp.
Plate 5, figure 10

A broken internal mold that has the anterior end missing suggests an original shell of about 3½ inches in length. The hinge line is straight, projecting above dorsal surface of mold; posterior margin sharply rounded from ventral area, curving upwards and joining posterior extremity of hinge line at about 45° angle; ventral margin slopes gently with reference to opposite side; umbonal ridges prominent. A little shell material remains showing smooth surface with well-marked concentric growth lines. The characteristics of the mold somewhat resemble those listed for *Modiola burlingtonensis* of the Merchantville clay-marl of the Upper Cretaceous of New Jersey.

Occurrence: In the conglomerate of the Coleraine formation, Arcturus mine, Marble, Minn.

OSTREA CONGESTA Conrad

Ostrea congesta CONRAD, 1843, in NICOLLET, Rept. of Explorations in the Northwest, p. 167.
Ostrea congesta, HALL, 1856, Pacific R. R. Reports, vol. 3, p. 100, pl. 1, fig. 11.
Ostrea congesta, MEEK, 1876, U. S. Geol. Survey Terr., vol. 9, p. 13, pl. 9, figs. 1a–f.
Ostrea congesta, WHITE, 1884, U. S. Geol. Survey Ann. Rept. 4, p. 294, pl. 39, figs. 11, 12, 13.
Ostrea congesta, STANTON, 1893, idem. Bull. 106, p. 55, pl. 2, figs. 2–4.

This little species is common in the shaly beds of the area. Practically all the Minnesota specimens have been separated from attachment, and none occur in groups cemented onto other shells as is characteristic of this form in so many localities. Some attain a slightly larger size than the usual form, and few have the sharp right angle deflection from the cemented area, most being deflected upward and outwards at about a 60° angle from a small cemented area. The lower valves are scoop-shaped with sides sloping from the flattened hinge area to the high ventral region produced by the sharp upward deflection of the valve. The

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EXPLANATION OF PLATE 4

All figures natural size.

FIGS. *1–13—Exogyra boveyensis* Bergquist, n. sp. Cotypes. *1–3*, Anterior, surface and side views of left valves showing plications. *4, 5*, Internal views of small left valves. *6, 7*, Opposite views of a right valve. *8, 9*, Surface views of large and medium-sized right valves showing laminae and plications. *10–13*, opposite views of right valves. Specimens figured in *7, 9, 11* from Coleraine formation at Hill Annex mine, Calumet, Minn.; remainder from Coleraine formation at Coleraine, Minn. (p. 16)

14–16—Exogyra sp. *14, 15*, Right valve and anterior part of a specimen preserving both valves in place. *16*, Surface view of a large right valve. Both specimens from Coleraine formation, Arcturus mine, Marble, Minn. (p. 18)

shape is somewhat modified by the object of attachment and by crowding. Upper valve is flattened or irregular, shape variable, surface marked by prominent growth lines and sometimes by radiating ribs; more commonly found than are the lower valves. *O. congesta* is a variable species, and the modification in the Minnesota forms is not so great that they need be excluded from the group.

Occurrence: In the shales of the Coleraine formation, Hill Annex mine, Calumet, Minn., and the Arcturus mine at Marble, Minn.; also in the mines at Coleraine and Bovey, Minn.

OSTREA GILEI Bergquist, n. sp.
Plate 6, figures 1–6, 10–13;
plate 7, figures 3–5

Shell of medium size, roughly obliquely subovate to subcircular in outline, curved towards rear, obliquely elongated in direction of height, strongly inequilateral, strongly inequivalve. Left valve flattened to concave or even slightly convex; attachment area variable, from dorsal third to entire under surface, commonly along entire posterior half of valve. Anterior area thickened and deflected gently or abruptly upwards, producing a convex or steep side as much as 10 and 15 mm. high; ventral area developed similarly but lower and may be flattened; anterior and ventral margins usually broadly curved; posterior margin flattened or distorted ventrally, rounded or gently curving or nearly straight to an extended dorsal area, sometimes thickened dorsally; beak obscured by attachment scar. Right valve convex, especially in early portion. Reflection of distorted lower valve produces a well-defined umbonal ridge in submedial region, continued past midheight and giving marked convexity to considerable portion of valve; anterior slope steeper, usually interrupted by a narrow furrow reflecting margin of attachment area of lower valve; furrow beginning at anterior end of ligament and curving directly or unevenly down to ventral or posteroventral margin, or may be joined by a similar posterior furrow at midheight or below, producing flattening in posteroventral, ventral and anteroventral regions; posterior furrow generally more pronounced and anterior one obscured. Anterior margin curving posteriorly and usually gently arched about midheight; ventral margin generally rounded continuously from anterior; posteroventral margin abrupt; posterior margin straight or gently curved, passing obliquely to dorsal area, which may be extended from hinge line; posterior region may show arching at one or more places. Beak small, slightly incurved over hinge line or inconspicuous. Dorsal margins straight. Hinge line roughly triangular, that of left valve may be widest anteriorly due to attachment scar, longest dimension measures 15 to 20 mm. along base, height above base 8 to 10 mm. on left valve, rarely as much as 15 mm.; ligament area 5 to 10 mm. high on right valve. Resilifers slightly triangular, deeper on left valve. Area marked by fine striations of the growth lines. Adductor scar large, wide below, narrowed above, curved upward along outer margin, broadest portion situated below midheight toward posterior margin; scar on right valve more elongated and narrower in direction of height.

Surface of right valve marked by concentric growth lines, which form strong undulations at intervals, especially in front of the convex area; some specimens show regular transverse costae on umbonal region. Left valve retains impression of radial costae and undulations of *Brachiodontes arcturusensis*, n. sp. to which many were attached. Beyond attachment area the surface is marked by concentric growth lines and undulations.

Dimensions of largest shell: oblique height, 60 mm.; length in dorsal area, 32 mm.; length in ventral region, about 45 mm.; maximum convexity, about 25 mm. Average subcircular left valves measure about 45 to 50 mm. in height and 40 to 45 mm. in maximum length.

Occurrence: In the shale and conglomerate of the Coleraine formation, Arcturus mine, Marble, Minn., and the Hill Annex mine at Calumet, Minn.; also from mines at Coleraine and Bovey, Minn.

Cotypes: Three showing both valves (Cat. No. 5027a) and several separate right and left valves, Cat. No. 5027, Geol. Museum, Dept. of Geology, University of Minnesota.

This species is named in honor of Mr. R. E. Gile, formerly of the Department of Geology, University of Minnesota.

OSTREA PRUDENTIA White

Ostrea prudentia WHITE, 1876, U. S. Geol. Survey W. 100th Mer., vol. 4, p. 171, pl. 14, figs. 2a–d.

Ostrea prudentia, WHITE, 1884, U. S. Geol. Survey, 4th Ann. Rept., p. 299, pl. 40, figs. 5, 6.

Ostrea prudentia, STANTON, 1893, idem, Bull. 106, p. 54, pl. 1, figs. 3, 4.

A number of shells appear to resemble this species closely enough to be placed under it. Right valves are suboval to subcircular in outline, flat or slightly convex, a few are a little concave transversely. The surface is somewhat roughened and shows prominent laminae on some specimens. Some of the specimens resemble somewhat varieties of *O. patina* Meek and Hayden of the Pierre shales. A few right valves that appear to belong to this species are larger than others assigned to it heretofore, being 9 to 9.5 cm. in height and 6 to 9 cm. in length.

Occurrence: In the shale and conglomerate of the Coleraine formation in the Hill Annex mine at Calumet, Minn., and the Arcturus mine at Marble, Minn.; also occurs in the mines at Coleraine, Minn.

OSTREA SOLENISCUS Meek, var.
Plate 7, figures 1, 2, 5, 6; plate 8, figures 1–4

Ostrea soleniscus MEEK, 1871, Am. Philos. Soc. Proc., vol. 11, p. 430.

Ostrea soleniscus, MEEK, 1873, U. S. Geol. Survey Terr. Rept. for 1872, p. 487.

Ostrea soleniscus, WHITE, 1880, idem for 1878, p. 9, pl. 11, figs. 2a, b.

Ostrea soleniscus, WHITE, 1884, U. S. Geol. Survey, 4th Ann. Rept., p. 300, pl. 42, fig. 1.

Ostrea cortex, WHITE, 1876, U. S. Geog. and Geol. Survey W. 100th Mer., vol. 4, p. 170, pl. 15, fig. 2a–e.

Ostrea soleniscus, STANTON, 1893, U. S. Geol. Survey Bull. 106, p. 56, pl. 2, fig. 1; pl. 3, figs. 1, 2.

Adult shell large, rugged, subovate to subcircular in outline. Left valve convex; usually flattened on posterior half, with anterior side rounded abruptly upwards; some specimens are irregularly flattened or gently convex over entire valve. Right valve flat to gently convex, subovate to subcircular in outline, anterior half more thickened than in posterior region. Ligament areas of both valves slightly curved, a large left valve measuring 45 mm. along base of ligament and 15 mm. in maximum height. Area below ligament deeply excavated in left valve. Adductor scars deep, situated about mid-height or a little below, close to posterior margin, ovate to subtrihedral, narrowed toward posterodorsal area of shell. Surface of both valves made very rugged by pronounced concentric laminae and pitting by corrosive agents and boring pelecypods. *Exogyra mesabiensis*, n. sp., is attached to some specimens.

Though the typical shells of this species are greatly elongated and narrow, broadly ovate forms similar to the Mesabi specimens are known from the southwestern states. Distorted individuals of this species show somewhat curved beaks and resemble larger members of *Exogyra lamellosa*, n. sp. but have a heavier left valve and lack the sharp projecting laminae characteristic of the right valve of the *Exogyra*.

Largest left valve measures: height, 13 cm.; length, 9.5 cm. A subcircular left valve is 11.5 cm. high and 10 cm. in length. Largest right valve is 10 cm. high and 6.5 cm. in length.

Occurrence: In the conglomerate of the Coleraine formation, Arcturus mine, Marble, Minn.

Cotypes: Several separate valves, Cat. No. 5029, Geol. Museum, Dept. of Geology, University of Minnesota.

OSTREA (ALECTRYONIA) STAUFFERI
Bergquist, n. sp.
Plate 9, figures 1–10

Shells somewhat variable in thickness, outline, and in degree of ornamentation. Small to medium size. Typical forms curve toward rear. Both valves about equally inflated; left valve may be deeper. Anterior margin of left valve of holotype rises abruptly to meet the sharp down-curved anterior margin of right valve; surfaces then slope to flattened posterior region. This relationship is true of all shells but not as pronounced on most. Scar of attachment on left valve varies in size, that on holotype covers about one-third of shell; some show smaller areas, while some are attached along entire under surface or along the posterior part of the shell. Many left valves are attached to right valves of other individuals so that posterior and ventral margins are flattened to down-curved. Some shells have a posterodorsal winglike extension, but this is

lacking on the holotype. Beaks not prominent, curved on some specimens.

Area of hinge line on holotype is wedge-shaped, 32 mm. at base, 11 mm. on anterior margin, and narrowed to 6 mm. on posterior margin; on others the area is roughly triangular; all show considerable curvature. Resilifer curved, broad and pronounced on left valve, may occupy about one-third of hinge area; closer to anterior margin than posterior. Adductor scar large, broad below, narrowest and indented above, situated close to posteroventral area.

Anterior margin of shell exhibits a series of deeply indented, geometrically V-shaped notches, giving sharply interlocking edges where valves meet. Along ventral margin these become less pronounced and usually are entirely lacking on posterior margin. Anterior surface of right valve generally ornamented by 10 to 12 prominent costae, immature forms show smaller number. Costae are V-shaped in cross section and continuous to the interlocked edges. These are not clearly defined on dorsal third or posterior portion of valve but are radiate and broadly curved from the frontal region, new ones added by bifurcation or intercalation. Costae tend to irregularity along crests. Because of the large attachment area, the lower valve does not always clearly show the costae, but generally 10 to 12 are indicated along the anterior and ventral margins, where the edges become sharply V-shaped. Some shells lack ribbing except along anterior marginal area, remainder of surface then being irregular and roughened only by growth lines.

Dimensions of holotype: height, 55 mm.; length, 28 mm.; maximum convexity of anterior margin, 32 mm.; maximum convexity of posterior margin, about 20 mm.

Occurrence: In the conglomerate and shale of the Coleraine formation, Arcturus mine at Marble; Hill Annex mine at Calumet; and mines at Coleraine and Bovey, Minn.

Types: Holotype, Cat. No. 5030a, showing both valves; 2 paratypes of paired valves Cat. No. 5030, and several paratypes of separate valves, Cat. No. 5030, Geol. Museum, Dept. of Geology, University of Minnesota.

This species is named in honor of Dr. C. R. Stauffer, Department of Geology, University of Minnesota.

OSTREA sp.
Plate 6, figures 7–9

Shell small, thin, irregularly subtriangular in outline, produced posteriorly. Left valve convex, beak small, distorted by attachment; anterior half rises abruptly from attachment area; ventral margin long because of a shallow, posterior lobelike extension, which is as long as major part of valve; posterior margin curved abruptly at posterodorsal region, from which it ascends obliquely to hinge area; surface marked by strong growth lines. Right valve flat to concavo-convex, subtriangular to rectangular in outline; beak small; surface of valve marked by strong growth lines and a few pronounced laminae. Specimens measure 10 to 25 mm. from anterior to posterior margins and 12 to 15 mm. in height.

Shells somewhat resemble small distorted forms of *O. congesta* Conrad and may be a variety of it, though all are extended posteriorly in the same manner.

Occurrence: In the green shales of the upper part of the Coleraine formation, southeast corner of Hill Annex mine, Calumet, Minn.

Figured specimen: Cat. No. 5031, Geol. Museum, Dept. of Geology, University of Minnesota.

EXOGYRA BOVEYENSIS Bergquist, n. sp.
Plate 4, figures 1–13

Lower valve subcircular in outline; thin; beak strongly twisted, some greatly distorted and hidden by attachment scar and covered by posterodorsal extension of valve, anterior margin high when posterior half is flattened or deflected downward with surface showing large attachment scar; valve convex and deeply excavated when attached only by umbo; deeply excavated beneath ligament. Ligament area narrow, strongly curved; strong crenulations below ends; adductor scar faint, nearly circular, located high. Surface marked by strong plications along anterior surface and crenulations posteriorly; a few are smooth.

Upper valve thin, usually nearly flat but may be irregular; rounded to elongate in outline; beak closely coiled and sometimes obscured by shell material, notched below. Ligament area bordered above by crenulated ridge; a short crenulated ridge occurs

below beak adjacent to marginal notch. Adductor scar nearly central. Margin of valve thickened from beak to front and deflected sharply above surface with laminae making sharp curved ridges; curved low plications radiate from beaks over surface of valve, these are broken at intervals by growth laminae. Dimensions of upper valves: maximum length, 51 mm. on a specimen 37 mm. high; a subcircular valve measures 38 mm. in height and 40 mm. in length.

Occurrence: In the shales and conglomerate of the Coleraine formation, Hill Annex mine at Calumet, Minn., and the Morrison mine and Walker Pit at Bovey, Minn.

Cotypes: Cat. No. 5012, separate valves, Geol. Museum, Dept. of Geology, University of Minnesota.

EXOGYRA LAMELLOSA Bergquist, n. sp.
Plate 2, figures 1–8; plate 3, figures 1–5, 10, 11, 20

Shell medium sized. Left valve subovate or else elongated in direction of height with outline strongly convex along anterior margin and gently convex along posterior margin; thickened along umbonal half, becoming thinner toward flattened posterior area; anterior margin rises sharply or is rounded upwards from thickened umbonal area. Beak strongly curved, but only a few show much of it preserved, being corroded on many specimens; attachment area occupies most of posterior part of valve and leaves an irregular surface; ligament area high, broad, and greatly developed on some, being as much as 20 mm. high on a few medium-sized specimens, curved, marked by growth lines, resilifer deep and wide; small crenulations sometimes visible on margins below ends of ligament area, and these may occasionally be traced onto the laminae of surface of shell; region under ligament area excavated on young shells but thick and nearly solid on old forms; adductor scar situated near posterior margin a little below midheight, broadest below, concave upwards, convex toward posterior margin. Valve flattened on posterior half, entire surface marked by coarse laminae, which have weathered to form an irregular and pitted effect. Greatest dimensions exhibited are 80 mm. for height on a valve 70 mm. long; an average specimen measures 52 mm. in length and 63 mm. in height; a large valve with the beak partly corroded measures 10 cm. in height and 8 cm. in length.

Right valve roughly lenticular to ovate in outline, convex and greatly thickened in umbonal area. Beak curved, usually defined below by marginal notch; posterior margin curving or indented with a small winglike development near dorsal area. Ligament area curved, resilifer not as deeply impressed as on left valve; a tiny pedal scar occurs a few millimeters below ligament area; minute crenulations occur beneath anterior and posterior ends of ligament area, these coalesce on laminae of sides of some individuals and give a striated effect; adductor scar large, narrowed above. Surface of right valve marked by heavy lamellae, which form sharp upturned ridges along anterior margin and represent resting stages of growth where margin fitted into left valve, lamellae usually abruptly curved in posteroventral area in accordance with outline of valve and continued more or less flattened along posterior region; a depressed area occurs along posterior umbonal slope. Senile forms are rough but do not show the upturned lamellae, apparently having been worn down. Dimensions of largest upper valve showing sharp ridges: beak to posteroventral extension, 66 mm.; maximum length parallel to hinge line, 50 mm. Dimensions of a subovate form: height, 50 mm., maximum length, 48 mm., base of ligament area, 28 mm. Dimensions of largest senile form: 10 cm. high; 7 cm. long.

Occurrence: In the Coleraine formation: in the shales and conglomerate in the Hill Annex mine, Calumet, Minn.; in the conglomerate of the Arcturus mine, Marble, Minn.; and in the shales and conglomerate of Canisteo-Walker pit at Coleraine and the Morrison pit at Bovey, Minn.

Cotypes: Several separate valves, Cat. No. 5015, Geol. Museum, Dept. of Geology, University of Minnesota.

EXOGYRA MESABIENSIS
Bergquist, n. sp.
Plate 3, figures 6–9, 12–19

Lower valve variable; subcircular to elongate in outline but may be distorted by object of attachment; cemented area usu-

ally large. Beak sharply twisted and hidden beneath a winglike extension of posterodorsal region; large attachment area, which sometimes comprises posterior half of valve with opposite side rising abruptly from the cemented area, giving a deepened region to anterior portion of valve; posterior margin usually flattened but may be irregular because of attachment to other shells; valve deeply excavated beneath ligament, especially when umbonal area is flared dorsally. Ligament high, curved, base straight, deeply grooved; minute crenulations below ends of ligament, anterior crenulations sometimes continued above ligament area. Adductor scar conspicuous, widest ventrally, narrowed above, convex posteriorly. Growth lines and coarse laminae mark surface of valve. Elongate specimens average about 25 mm. in highest dimension and about 25 mm. in length.

Upper valve thin, flattened, but irregular; beak inconspicuous and not always greatly coiled. Ligament high. Anterior margin of valve deflected upwards, forming a sharp ridge; surface marked by laminae and occasional plications.

Occurrence: In the conglomerate of the Coleraine formation, Hill Annex mine at Calumet, Minn., and the Canisteo-Walker pit, Coleraine, Minn.

Cotypes: Separate valves, Cat. No. 5016, Geol. Museum, Dept. of Geology, University of Minnesota.

EXOGYRA SUBORBICULATA (Lamarck)

Gryphaea suborbiculatc LAMARCK, 1802, Système des animaux sans vertèbres, p. 398.
Exogyra suborbiculata, STANTON, 1893, U. S. Geol. Survey Bull. 106, p. 62, pl. 5, fig. 6; pl. 6, figs. 1, 2; pl. 8, fig. 1. (Includes other references.)

This is one of the commonest forms found in the area. In the shaly beds the left valves are partially broken, but the shell material is well preserved. In the sandstone and conglomerate the shells are chalky and usually only the internal molds are present. The left valves show considerable variation, the beaks are sometimes flattened or are free and undistorted. A few valves show radial costae on the umbonal area or in the vicinity of the beaks. The specimens show the ligamental groove to be narrow, deeply impressed, curved; posterior to the groove and below it is a shallow pitted area, which may be extended as a thickened plate and is sometimes obliquely inclined and curved upwards as a ridge onto the posterodorsal part of the shell, which is occasionally produced dorsally so that it flares up over the beak.

The internal molds indicate the size of entire shells and the deep excavation of some of the left valves; impressions of adductor scars of both valves are clearly seen; some molds show a raised prominence on the umbonal slope adjacent to the adductor scar of the left valve; radial costae are sometimes indistinctly visible.

Occurrence: In the shales and conglomerate of the Coleraine formation in the Canisteo-Walker pits at Coleraine, Minn.; the Morrison pit at Bovey, Minn. Internal molds from the conglomerate of the same formation in the Hill Annex mine, Calumet, Minn. and the Arcturus mine, Marble, Minn.

EXOGYRA sp.
Plate 4, figures 14–16

One complete specimen with both valves in place and a large right valve show the

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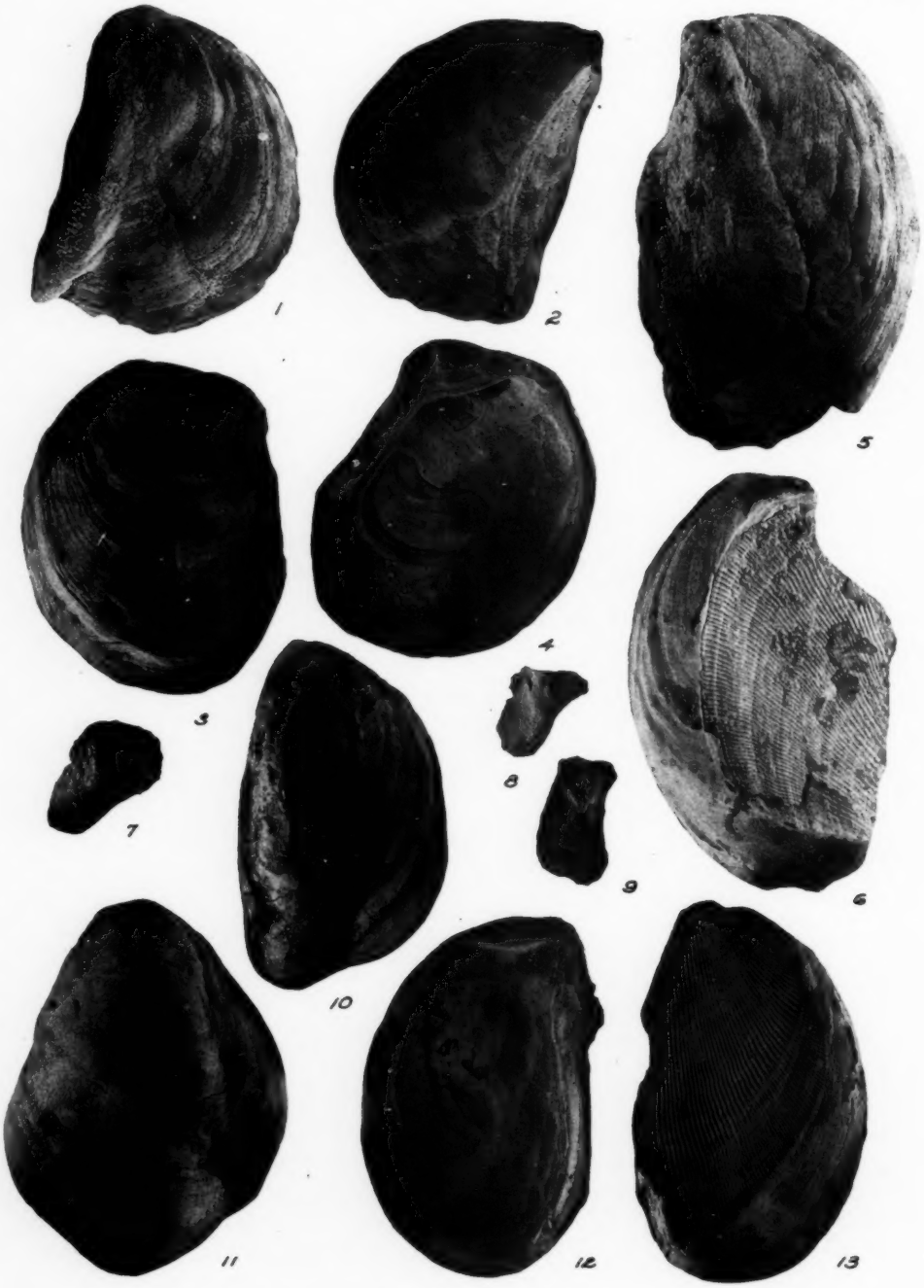
EXPLANATION OF PLATE 5
All figures natural size.

FIGS. *1, 2, 7, 9—Brachidontes arcturusensis* Bergquist, n. sp. Cotypes. *1, 7, 9*, Internal molds showing right valves; plications retained on two specimens. *2*, Left valve of a small internal mold retaining some inner shell substance; Coleraine formation at Coleraine, Minn. Specimens figured in *1, 7* from Coleraine formation, Arcturus mine, Marble, Minn. Specimen figured in *9* from Coleraine formation at Coleraine. (p. 20)

3–6, 8—Inoceramus fragilis mesabiensis Bergquist, n. var. Cotypes. *3, 8*, Anterior end and right valve of a large internal mold. *4*, Left valve of a large internal mold. *5, 6*, Right and anterior views of a small internal mold. Specimens from conglomerate of Coleraine formation, Hill Annex mine, Calumet, Minn. (p. 12)

10—Volsella sp. Broken internal mold of a specimen which has only growth lines on surface and lacks plications; Coleraine formation, Arcturus mine, Marble, Minn. (p. 13)

Bergquist, Cretaceous Fossils



Bergquist, Cretaceous Fossils

following characteristics: shell semicircular in outline, being strongly curved from beak to posteroventral area and straight from there to the beak. Left valve attached by almost entire posterior half of valve with anterior half curved abruptly upwards from attachment; beak obscured; surface corroded. Right valve flat, same outline as for entire shell; beak strongly curved; surface marked by curved lamellae and strong growth lines.

Occurrence: In the conglomerate of the Coleraine formation, Arcturus mine, Marble, Minn.

Figured specimen: Cat. No. 5017, Geol. Museum, Dept. of Geology, University of Minnesota.

PECTEN (CAMPTONECTES) PLATESSUS (White)

Camptonectes platessa WHITE, 1874, Expl. and Sur. W. 100th Mer. Prelim. Rept. Invert. Fossils, p. 25.

Camptonectes platessa, WHITE, 1876, U. S. Geog. and Geol. Survey W. 100th Mer., vol. 4, p. 176, pl. 17, fig. 5a.

Camptonectes platessa, STANTON, 1893, U. S. Geol. Survey Bull. 106, p. 72, pl. 9, fig. 6.

Internal and external molds of both valves, some preserving shell material, are found in the conglomerate of the region. None are entirely complete, and the ears are usually only partly preserved. The characteristic subcircular outline of the species and the *Camptonectes* type of sculpturing, however, can be readily discerned.

A number of impressions of this species occurs in the green shale of the Hill Annex mine. The specimens range from 8 mm. in diameter to adult forms. The shell material is very thin and usually chips and crumbles when the shale covering is removed. The surface markings are fine on the small forms and are not readily discernible without a lens.

Occurrence: Coleraine formation; Conglomerate in the south face of the Hill Annex mine at Calumet, Minn.; in the green shales in the southeast corner of the same mine; in the conglomerate of the Arcturus mine, Marble, Minn.

PECTEN (CAMPTONECTES) PLATESSUS (White), var.?
Plate 10, figures 3, 4

In addition to the subcircular shells there are a few molds of a small subovate form having a transverse diameter about three-fourths the height of the shell. The hinge line is about two-thirds the transverse diameter and is slightly inclined to the axis of the shell, being highest anteriorly. The auricular furrows diverge at right angles to each other and continue straight to shell margins, the anterior one showing slight concavity. Ears known only for left valves. Surface marked by characteristic costae, which cross auricular furrows and curve upwards on the ears.

Occurrence: In the conglomerate of the Coleraine formation, Hill Annex mine at Calumet, Minn. and Arcturus mine at Marble, Minn.

Figured specimens: Cat. No. 5034, Geol. Museum, Dept. of Geology, University of Minnesota.

LIMA UTAHENSIS Stanton

Lima utahensis STANTON, 1893, U. S. Geol. Survey Bull. 106, p. 71, pl. 9, fig. 5.

The species is represented by a nearly complete left valve and by two other left

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EXPLANATION OF PLATE 6

All figures natural size.

FIGS. *1–6, 10–13—Ostrea gilei* Bergquist, n. sp. Cotypes; all from Coleraine formation in Arcturus mine, Marble, Minn. *1, 2*, Right and left valves of a shell having both valves in place. *3, 4*, Opposite views of a left valve with small attachment scar. *5, 6*, Right and left valves of a large shell having both valves in place, left valve showing a large attachment scar preserving pattern of plications of *Brachidontes arcturusensis*, n. sp. *10*, View of a right valve showing furrow continued to ventral margin, surface somewhat plicated. *11*, A very convex right valve. *12, 13*, Internal and external views of a left valve, the latter showing large attachment scar preserving pattern of plications of *Brachidontes arcturusensis*, n. sp. (p. 14)

7–9—Ostrea sp. *7, 8*, Left valves; *9*, A flattened right valve. Specimens from green shales of Coleraine formation, Hill Annex mine, Calumet, Minn. (p. 16)

valves, which do not show the features so clearly. The under surfaces cannot be seen, the shells being embedded in sandstone. The ears are almost complete on the best specimen, and most of the shell material is preserved, showing the coarse, regular radiating costae.

Occurrence: In the ferruginous grit of the Coleraine formation, south face of Hill Annex mine, Calumet, Minn.

ANOMIA PROPATORIS White

Anomia propatoris WHITE, 1880, U. S. Geol. Survey Terr. Rept. for 1878, p. 14, pl. 12, figs. 15a–b.

Anomia propatoris, STANTON, 1893, U. S. Geol. Survey Bull. 106, p. 67, pl. 8, fig. 10.

Represented by the external mold of a left valve retaining some of the translucent shell substance. The fine radiating striations are visible over the entire surface and are crossed by irregular concentric wrinkles. A squeeze from the mold reveals the features clearly.

Occurrence: In the green shale of the Coleraine formation, southeast corner of Hill Annex mine, Calumet, Minn.

BRACHIDONTES ARCTURUSENSIS
Bergquist, n. sp.
Plate 5, figures 1, 2, 7, 9;
plate 6, figures 6, 13

Shell obliquely arcuate to roughly triangular in outline; equivalve, biconvex, greatest convexity occurring about midpoint on umbonal slopes. Beaks not prominent, nearly terminal, projecting slightly beyond hinge line. Molds exhibit a deep furrow beginning on beak and curving sharply toward anterior margin marking off a small lobate area. Umbonal ridges prominent, sloping obliquely or curving to anteroventral margin. Anterior umbonal slope abrupt to nearly vertical, latter forms exhibit sharp umbonal ridges; dorsal and anterior slopes marked by a continuous groove near base, producing a slight flange along margin, observed only on molds; dorsal slope rounded; posterior and ventral slopes gentle, with a flattening in posterodorsal area on some shells. Hinge line straight to gently convex, length a little less than half the measured distance from beak to ventral margin; posterodorsal margin broadly curved downward through a broad arc to the abruptly rounded posteroventral margin; anterior margin oblique to hinge line, some shells show a slight concavity about midlength.

Surface marked by fine growth lines, which form strong concentric undulations at intervals and are crossed by regular radiating costae that are almost uniform over entire surface but are wavy where stronger growth lines intercept.

Dimensions of shells: Dimensions of one individual; hinge line, 32 mm.; greatest oblique length, 50 mm.; greatest breadth, 32 mm.; greatest convexity of left valve, 10 mm. A large broken specimen suggests an oblique length of about 90 mm.; maximum breadth, 48 mm.; convexity of left valve, 17 mm. A distorted specimen measures 85 mm. along oblique length; 38 mm. for maximum width; about 15 mm. for convexity of right valve.

Occurrence: In the Coleraine formation. Internal molds are very abundant in ferruginous grit of the Arcturus mine at Marble and occur in similar material in the south face of the Hill Annex mine at Calumet and in mines near Coleraine, Minn. They also occur in the green shale bed in the southeast corner of the Hill Annex mine.

Cotypes: Several nearly complete internal molds showing both valves and some of the shell substance. Cat. No. 5023, Geol. Museum, Dept. of Geology, University of Minnesota.

PHOLADOMYA COLORADOENSIS Stanton
Plate 9, figures 11, 12

Pholadomya coloradoensis STANTON, 1893, U. S. Geol. Survey Bull. 106, p. 116, pl. 26, fig. 2.

Only two internal molds were found. One was nearly complete, whereas the other was badly crushed but retained a little of the thin shell substance embedded in shale. The specimens show the following features.

Shell thin, medium sized, obliquely subovate in outline, strongly inequilateral, regularly convex along umbonal region; posterior apparently gaping; anterior margin curving obliquely downward towards rear from dorsal area and continuous into ventral margin, describing an oblique semiovate curve; posterior margin rounded above and below; hinge line slightly depressed below anterior

and posterior ends; beaks broken but apparently broad, strongly incurved and rising well above hinge line, situated near anterior end. Surface of each valve ornamented by about 20 radiating wavy costae, closest on umbonal area, recurved in anterior and posterior regions; concentric growth lines and undulations cover the surface, where plications are crossed a suggestion of tubercules appears. Greatest oblique length, about 42 mm.; height posterior to beaks, about 25 mm.; convexity 20 mm.

The Minnesota form appears to differ from Stanton's western type in having fewer costae and a small anterior end narrowed by an extremely oblique curvature of the anterior margin. This may prove to be a new species.

Occurrence: In the shales of the Coleraine formation, Hill Annex mine at Calumet, Minn., and at Coleraine, Minn.

Figured specimen a nearly complete internal mold: Cat. No. 5035, Museum, Dept. of Geology, University of Minnesota.

ANATINA MARBLENSIS
Bergquist, n. sp.
Plate 1, figures 3, 4

Internal molds subovate in outline, laterally compressed, equivalve, inequilateral. Beaks small, directed posteriorly, fissured transversely to produce a sharp ridge and undercutting of beaks, situated a little behind central position and rising slightly above anterior hinge area but considerably above posterodorsal margin. Pallial line not defined. Posterior adductor muscle scar small, marginal in position. A deep fissure present on each valve beginning along posterior adductor scar and passing upward at 45° angle to hinge line, deeply penetrating the beaks. Anterodorsal margin sloping about 30° from area of beaks; anterior margin sharply rounded and continuing into broadly rounded ventral margin; posterodorsal margin rather steeply inclined from below beaks; posterior margin sharply rounded. Shell probably relatively thin, for surface of molds show numerous strong, concentric, irregular growth ridges but they are not visible in posterior region. Normal to ventral margin are short fine fissures crossing the growth ridges.

Dimensions: Cotype 5002a, height 48 mm., length 62 mm., width 20 mm.; cotype 5002b, height 54 mm., length 62 mm., width 14 mm. (specimen crushed); cotype 5002c, height 14 mm., length 19 mm., width 5 mm.

Occurrence: In the conglomerate of the Coleraine formation, northeast corner of Arcturus mine, Marble, Minn.

Cotypes: Cat. No. 5002, Geol. Museum, Dept. of Geology, University of Minnesota.

ANATIMYA PLICATA Bergquist, n. sp.
Plate 1, figures 1, 2, 5

Internal molds, subovate to subelliptical in outline, equivalve, inequilateral, moderately biconvex. Beaks small, almost central in position, not prominent, each cut by shallow transverse fissure and sharply defined from posterior area by deep fissures, which begin horizontally beneath either beak and curve sharply downward for about one-third of height of shell, which is likewise the point of greatest convexity of valves. Valves gaping posteriorly. Teeth and muscle scars unknown. Anterodorsal margin sloping about 30° to rounded anterior margin; ventral margin long, curving broadly but slightly incurved opposite the beaks, with valves constricted in this midportion; posterior margin incomplete on all specimens but apparently broadly rounded; posterodorsal margin nearly straight anteriorly adjacent to beaks but sharply rounded toward posterior margin.

Shell apparently thin, surface of molds marked by strong, irregular concentric ridges, which are best developed on anterior half of shell; posterior half marked by 8 to 12 costae, which radiate from posterior portion of beaks but all are curved toward posteroventral margin. Anterior to the costae, in midportion of shell, is an area where concentric ridges are less pronounced but fine striations occur normal to ventral margin.

Dimensions: Cotype 5003a, height 45 mm., length about 68 mm., width 21 mm.; cotype 5003b, height 45 mm., length 68–70 mm., width 20 mm.; cotype 5003c, height 50 mm., length about 63 mm., width 18 mm.

Occurrence: In the conglomerate of the Coleraine formation, northeast corner of Arcturus mine, Marble, Minn.

Cotypes: Cat. No. 5003, Geol. Museum, Dept. of Geology, University of Minnesota.

ETEA? sp.

Two partly crushed internal molds somewhat resemble *Etea carolinensis* Conrad in the Ripley formation of the Eastern and Gulf States. The basal margin of the Minnesota form is nearly straight instead of convex anteriorly and concave posteriorly. In other respects the two forms have similarities.

Occurrence: In the conglomerate of the Coleraine formation, Hill Annex mine, Calumet, Minn. and in the Arcturus mine at Marble, Minn.

CARDIUM ENSTROMI
Bergquist, n. sp.
Plate 1, figures 6, 7, 12

The dimensions of an internal mold complete except for right beak are: height, 38 mm.; length, 34 mm.; convexity, 33 mm. Roughly subovate in lateral view and cordate in end view. Hinge line arcuate; anterior and ventral margins broadly rounded and describing nearly a semicircle from anterior dorsal extremity to posteroventral margin, which is abruptly truncated; posterior margin straight, inclined slightly to dorsal area. Beaks nearly central, prominent, elevated, pointed and incurved. Valves biconvex, greatest along umbonal area; posterior slope more abrupt than anterior. Anterior adductor scars prominent and strongly impressed, transversely ovate, flattened above; posterior scars small, lenticular, inclined to hinge line. Hinge line indicates each valve had a strong curved cardinal tooth and pit for tooth of opposite valve beneath beaks; suggestion of anterior and posterior lateral teeth, especially pronounced anteriorly. Inner free margin of valves crenulated; slight impression of radiating costae towards edges of valves.

Broken external molds indicating that the surface was covered by regular numerous, sharp or flattened plications separated by interradial areas of equal or greater width (each 1 mm. wide along margin of holotype). Plications bearing numerous spines, which are strongest in anterior and posterior regions of portion of specimen preserved; spines on every other costae on lateral surface but on anterior and posterior regions strong spines occurring usually on every third costae but small ones may be present on some of the intervening ribs.

Internal mold greatly resembles some specimens of *C. tenuistriatum* (Whitfield) of the Upper Cretaceous of the Atlantic and Gulf regions.

Occurrence: In the conglomerate of the Coleraine formation, Hill Annex mine, Calumet, Minn. and in the Arcturus mine, Marble, Minn.

Holotype: Internal mold and broken external mold of same, Cat. No. 5006, paratypes, internal and external molds (external ones broken), Cat. No. 5007, Geol. Museum, Dept. of Geology, University of Minnesota.

This species is named in honor of Mr. Roger Enstrom of Bovey, Minn., who has collected numerous fossils and donated the holotype of this species.

LEGUMEN cf. L. PLANULATUM
(Conrad)

Solemya planulata CONRAD, 1853, Acad. Nat. Sci. Philadelphia Jour., ser. 2, vol. 2, p. 274, pl. 24, fig. 11.

Legumen planulatum, WELLER, 1907, New Jersey, Geol. Surv. Paleontology, vol. 4, p. 612, pl. 69, figs. 3–7.

A number of nearly complete internal molds compare closely with the characteristics of those from the Upper Cretaceous of the Atlantic and Gulf regions and the Montanan of Wyoming.

Occurrence: In the conglomerate of the Coleraine formation, northeast corner of

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EXPLANATION OF PLATE 7

FIGS. *1, 2, 5, 6—Ostrea soleniscus* Meek, var. *1, 6*, Opposite views, ×1, of a small flattened left valve; surface irregular. *2, 5*, Opposite views of a large valve, ×¾, showing rough exterior and the deep adductor scar; flattened posterior half; tubes of *Serpula bicarinata*, n. sp. attached on internal surface. Specimens from Coleraine formation, Arcturus mine, Marble, Minn. (p. 15)

3, 4—Ostrea gilei Bergquist, n. sp. Opposite views, ×1, of a right valve showing furrow continued to posterior margin. Cotype; from Coleraine formation, Arcturus mine, Marble, Minn. (p. 14)

Bergquist, Cretaceous Fossils

Bergquist, Cretaceous Fossils

Arcturus mine, Marble, Minn., and from Hill Annex mine, Calumet, Minn.

TAPES CYPRIMERIFORMIS Stanton

Tapes cyprimeriformis STANTON, 1893, U. S. Geol. Survey Bull. 106, p. 106, pl. 24, figs. 1–6.

Incomplete internal molds, a few showing impressions of teeth. The majority are smaller than the dimensions assigned by Stanton. Most are more nearly subovate than subcircular being longer than high but not differing sufficiently to be considered as a distinct species.

Occurrence: In the conglomerate of the Coleraine formation, Arcturus mine, Marble, Minn., and in the south face of Hill Annex mine, Calumet, Minn.

TAPES sp.

Several broken internal molds show the dentition and general features of this genus but could not be compared to known forms. Molds elongate-ovate to subcircular in outline, beaks incurved and directed forward, basal margin elliptical; surface marked by strong regular concentric ridges, which are likewise shown on external molds; shell apparently thin.

Occurrence: In the conglomerate of the Coleraine formation, Hill Annex mine, Calumet, Minn.

TELLINA CALUMETENSIS Bergquist, n. sp.

Plate 9, figures 13, 14

Represented by three internal molds; subtrihedral in outline, compressed, beaks slightly posterior; posterior margin broadly rounded, anterior margin more narrowed, ventral margin nearly straight; pallial sinus broad, deep, extending beyond midlength, posterior extension sharp; posterior adductor small, anterior adductor large; impression of only one cardinal tooth observed for each valve. Surface marked by faint radiating striations and two or three pairs of strong vascular furrows anterior to beaks and one pair posterior to beak; strong concentric lines indicated at intervals. Largest paratype is 31 mm. in length and 20 mm. in height.

Occurrence: In the conglomerate of the Coleraine formation, Hill Annex mine, Calumet, Minn.

Holotype: Cat. No. 5042 and two paratypes (5042a), Geol. Museum, Dept. of Geology, University of Minnesota.

LEPTOSOLEN BIPLICATUS (Conrad)

Siliquaria biplicata CONRAD, 1858, Acad. Nat. Sci. Philadelphia Jour., ser. 2, vol. 3, pl. 324, pl. 34, fig. 17.

Leptosolen biplicata, CONRAD, 1867, Am. Jour. Conchology, vol. 3, pp. 15, 188.

Leptosolen biplicata, WELLER, 1907, New Jersey Geol. Surv. Paleontology, vol. 4, pp. 624–626, pl. 70, figs. 30, 31.

This species is represented by several internal and external molds, some retaining a little of the thin shell. The fossils appear to be identical with the species which occurs in the Upper Cretaceous beds of the Eastern and Gulf states.

Occurrence: In the green shale of the Coleraine formation in southeast corner of Hill Annex mine, Calumet, Minn.

SILIQUA HUERFANENSIS Stanton

Siliqua huerfanensis STANTON, 1893, U. S. Geol. Survey Bull. 106, p. 114, pl. 25, figs. 10, 11.

Several internal molds exhibit sufficient characteristic features to identify them with those described by Stanton from the *Pugnellus* sandstone in Colorado and from the Colorado formation in Utah.

Occurrence: In the conglomerate of the Coleraine formation, northeast corner, Arcturus mine, Marble, Minn.

EXPLANATION OF PLATE 8

All figures ×$\frac{3}{4}$

FIGS. *1–4*—*Ostrea soleniscus* Meek, var. *1*, Anterior side of a distorted shell with both valves in place; an *Exogyra lamellosa*, n. sp., is attached to right valve. *2*, *3*, Opposite views of a large convex right valve; surface pitted by boring mollusca and by corosion. *4*, Surface view of left valve of specimen shown in *1*, surface irregular and flattened on posterior half of specimen (lower part of picture). Specimens from Coleraine formation, Arcturus mine, Marble, Minn. (p. 15)

CYMBOPHORA EMMONSI (Meek)?

Mactra? emmonsi MEEK, 1877, U. S. Geol. Expl. 40th Par., vol. 4, pt. 1, pl. 153.
Mactra emmonsi, STANTON, 1893, U. S. Geol. Survey Bull. 106, p. 121, pl. 27, figs. 9–13.

A few internal molds of single valves occur in the shales. The thin shell crumbles readily and little adheres to the specimens. The molds are small, not over 12 mm. in height and 16 mm. in length. Nothing of the internal characters nor hinge structure can be seen, but the specimens of Meek and those of Stanton likewise revealed only external characters and with these features the Minnesota forms check fairly well.

Occurrence: In the green shale of the Coleraine formation, southeast corner of Hill Annex mine, Calumet, Minn.

CYMBOPHORA UTAHENSIS (Meek)?
Plate 1, figures 8, 11, 13–16

Mactra (*Cymbophora*) *utahensis* MEEK, 1877, U. S. Geol. Expl. 40th Par., vol. 4, pt. 1, p. 155, pl. 15, figs. 9–9b.
Mactra (*Cymbophora*) *utahensis*, STANTON, 1893, U. S. Geol. Survey Bull. 106, p. 120, pl. 27, figs. 16, 17.

The Mesabi material indicates shells smaller than Meek's specimens but features are similar so they are included under that form. Internal molds with some chalky shell material on them are very common in some places in an indurated sandstone matrix of the conglomerate. The following characteristics are present on the Minnesota specimens:

Shell small, inequilateral, moderately convex, height about three-fourths of length. Beaks subcentral, rising a little above hinge line, strongly incurved and directed slightly forward; posterior umbonal slope defined by angular truncation from beak to posteroventral margin, most pronounced above. Dorsal margin gently curved, a little greater anteriorly; anterior margin rounded equally above and below; ventral margin nearly straight; posterior margin oblique, rounded abruptly in posteroventral area, subtruncate in posterodorsal area. Teeth and interior unknown. Maximum size: height 14 mm.; length, 19 mm. Many individuals are much smaller. Surface marked by fine growth lines and by occasional concentric crenulations; faint radial furrows indicated on ventral area of some specimens.

Some of the free specimens show a resemblance to *Schizodesma appressa* Gabb of the Atlantic and Gulf regions.

Occurrence: Indurated sandstone matrix of conglomerate of the Coleraine formation, Arcturus mine at Marble, Minn., and in the area of Coleraine, Minn.

CORBULA KANABENSIS Stanton

Corbula kanabensis STANTON, 1893, U. S. Geol. Survey Bull. 106, p. 125, pl. 27, figs. 5, 6.

A few small internal molds preserving some of the shell occur in the green shale at Calumet. Only single valves are represented, but these check with Stanton's species in the shape, contracted and angular posterior end, and flattened band along the basal margin.

Occurrence: In the green shale of the Coleraine formation in southeast corner of Hill Annex mine, Calumet, Minn.

PARAPHOLAS SPHENOIDEUS (White)

Turnus sphenoideus WHITE, 1876, Geology Uinta Mts., p. 117.
Parapholas sphenoideus, WHITE, 1879, U. S. Geol. and Geog. Survey Terr., Rept. for 1877, p. 300, pl. 5, figs. 1a–d.
Parapholas sphenoides, STANTON, 1893, U. S. Geol. Survey Bull. 106, p. 125, pl. 27, figs. 1, 2.

Three well developed specimens and several tiny ones belonging to this species were found in fossilized wood in the Hill Annex mine. The shells of two are well preserved, showing the surface markings; the third of the larger specimens is a stony internal mold.

TEREDOLITES sp.
Plate 10, figure 1

Pieces of logs found in the conglomerate contain compact masses of the fillings of tubes of *Teredo*-like pelecypods. The tubes are straight to wavy or even curved, gradually enlarging. The larger tubes continue to the central area of the wood and some of these attain sizes of 10 to 15 mm. in diameter at the rounded knoblike termination, while flattened tubes are up to 25 millimeters in the widest extension. Smaller tubes are packed in around larger ones making great aggregates. The largest mass is a specimen 7 inches by 4½ inches in width and 4 to 5 inches in length, the entire piece is

completely filled by hundreds of tubes, with only a little carbonized wood remaining in the small interspaces. All tubes are filled by a fine hard sandstone, some of which is pyritic. The irregular tubes suggest *T. irregularis* Gabb of the Upper Cretaceous of the east coast. The tubes are either smooth or show constrictions at intervals. Nothing of the shells of the organism which constructed the tubes could be found.

Occurrence: In the conglomerate of the Coleraine formation, Hill Annex mine, Calumet, Minn.

GASTROPODA

CALLIOMPHALUS? COLERAINENSIS
Bergquist, n. sp.
Plate 11, figures 10, 11, 16–19

Internal molds retaining a little shell substance indicate a medium-sized shell, trochoid, deeply umbilicate; spire moderately elevated, whorls four or five, subcircular to subquadrate in cross section, closely appressed and embedded into each other, indicating a thin shell; diameter of whorls gradually increasing, lateral extension increasing rapidly; sutures deep. External molds show surface to be ornamented by regular tuberculated revolving ridges; some indication of this may be seen on the internal molds. Seven revolving ridges occur on the posterior slope and about the same number on the basal area. The largest specimen has a height of about 18 mm. and a maximum diameter of about the same. Small specimens are about 9 mm. in height and diameter.

This genus has not been reported previously for the Colorado series. It is somewhat similar to *C. americanus* Wade of the Ripley formation from Coon Creek, Tenn., but that species is smaller, shows more ridges on both the posterior slope and on the basal area and has a series of tubercles along the umbilical keel.

Occurrence: In the Coleraine formation; internal molds from conglomerate in the northeast corner of the Arcturus mine, Marble, Minn., and external molds from the conglomerate in the south face of the Hill Annex mine at Calumet, Minn.

Cotypes: Internal and external molds; Cat. No. 5048, Geol. Museum, Dept. of Geology, University of Minnesota.

NERITA? MINNESOTENSIS
Bergquist, n. sp.
Plate 11, figures 12–14, 20, 21

Internal molds small, largest having a maximum oblique diameter of 20 mm. and a height of 12 mm.; subglobose from rear, obliquely trancate in front, depressed; volutions of shell probably about three (only two are indicated on mold, as earlier whorls are obscured on interior of shells of this genus); body whorl comprising most of the shell; suture obliterated in initial portion of mold due to absorption of early part of inner wall as shell was enlarged, suture present only along two-thirds of body whorl, expanding abruptly adjacent to aperture; aperture semicircular, straight on inner margin, outer margin indented in posterior region; expanded suture indicating that inner lip was broad and flattened; inner lip provided with six denticles, the two middle ones being strongest and the most anterior one least developed; these denticles are indicated on molds by grooves which extend for a short distance back from the aperture; anterior end of inner lip greatly thickened, as indicated by deep excavation in mold beside anterior margin of aperture. Outer lip thin-edged. A thick shell is suggested by the space between internal and external molds; surface marked by growth lines and faint spiral lines; internal molds smooth except for an occasional growth line, sometimes marked by spiral lines in area behind anterior sulcus. Operculum unknown.

Occurrence: South face of Hill Annex mine, Calumet, Minn., in the conglomerate of the Colerate formation and in the same material in the northeast corner of the Arcturus mine at Marble, Minn.

Cotypes: Internal molds; Cat. No. 5051, Geol. Museum, Dept. of Geology, University of Minnesota.

EPITONIUM sp.

Fragmentary material showing both internal and external molds indicate the following features: sutures well marked, whorls convex, surface marked by strong axial ribs (eight on one-half of shell); three whorls of largest specimen are about 25 mm. in height, body whorl 18 mm. in width. The

material on hand is too poor to determine specifically.

Occurrence: In the conglomerate of the Coleraine formation, Hill Annex mine, Calumet, Minn.

POLINICES CONCINNA (Hall and Meek)

Natica concinna HALL and MEEK, 1856, Am. Acad. Arts and Sci. Mem., n. s., vol. 5, p. 384, pl. 3, figs. 2a–d.
Lunatia concinna, MEEK, 1876, U. S. Geol. Survey Terr., vol. 9, p. 314, pl. 32, figs. 1a–c.
Lunatia concinna, WHITFIELD, 1880, Geol. Black Hills of Dakota, p. 430, pl. 12, fig. 13.
Lunatia concinna, STANTON, 1893, U. S. Geol. Survey Bull. 106, p. 134, pl. 29, figs. 9, 10.

This is one of the most abundant of the gastropods of the region. Internal molds show the deep sutures which freely separate the whorls. Squeezes made from external molds indicate the features described for the species.

Occurrence: In the conglomerate of the Coleraine formation, Hill Annex mine, Calumet, Minn.

GYRODES CONRADI Meek

Gyrodes conradi MEEK, 1876, U. S. Geol. Survey Terr., vol. 9, p. 310, figs. 33–36.
Gyrodes conradi, STANTON, 1893, U. S. Geol. Survey Bull. 106, p. 136, pl. 29, figs. 7 and 8.

This species is represented by a few internal molds. They are much larger than those described by Meek, approaching in size the smaller forms of *G. major* Wade from the Ripley fauna at Coon Creek, Tenn. Nothing is preserved to indicate the external surface features except umbilical molds, which show great lines. Dimensions of a nearly complete specimen are: height, 30 mm.; maximum breadth, 40 mm.; height of aperture, 33 mm.; width below middle, 20 mm. Another specimen showing only the last whorl but having the umbilical mold preserved, suggests a height of nearly 50 mm.

Occurrence: In the conglomerate of the Coleraine formation, Hill Annex mine, Calumet, Minn.; one specimen from the Arcturus mine at Marble, Minn.

APORRHAIS (LISPODESTHES) NUPTIALIS (White) Plate 11, figures 6–9

Anchura nuptialis WHITE, 1874, Expl. Survey W. 100th Mer., Prelim. Rept. Invert. Fossils, p. 24.
Lispodesthes nuptialis, WHITE, 1876, U. S. Geol. and Geog. Survey W. 100th Mer., vol. 4, p. 192, pl. 18, figs. 3a–b.
Lispodesthes nuptialis, STANTON, 1893, U. S. Geol. Survey Bull. 106, p. 147, pl. 31, figs. 5, 6.

This species is common in the conglomerate of the Hill Annex mine. Internal molds are well preserved, being attached by the extended lip of the body whorl. Most of them are larger than those figured by Stanton and by White, being as much as 30 mm. in height. They also differ slightly in surface ornamentation and in having a shorter anterior canal. Molds are subfusiform, about five whorls preserved, spire tapering and about two-thirds length of body whorl and anterior canal; outer lip extended into a wing, which terminates as a sharp spur parallel to the spire. A ridge begins on midline of body whorl near the aperture and continues to the posterior extremity of the wing. Anterior canal short, curved backwards. Squeezes of the exterior show that

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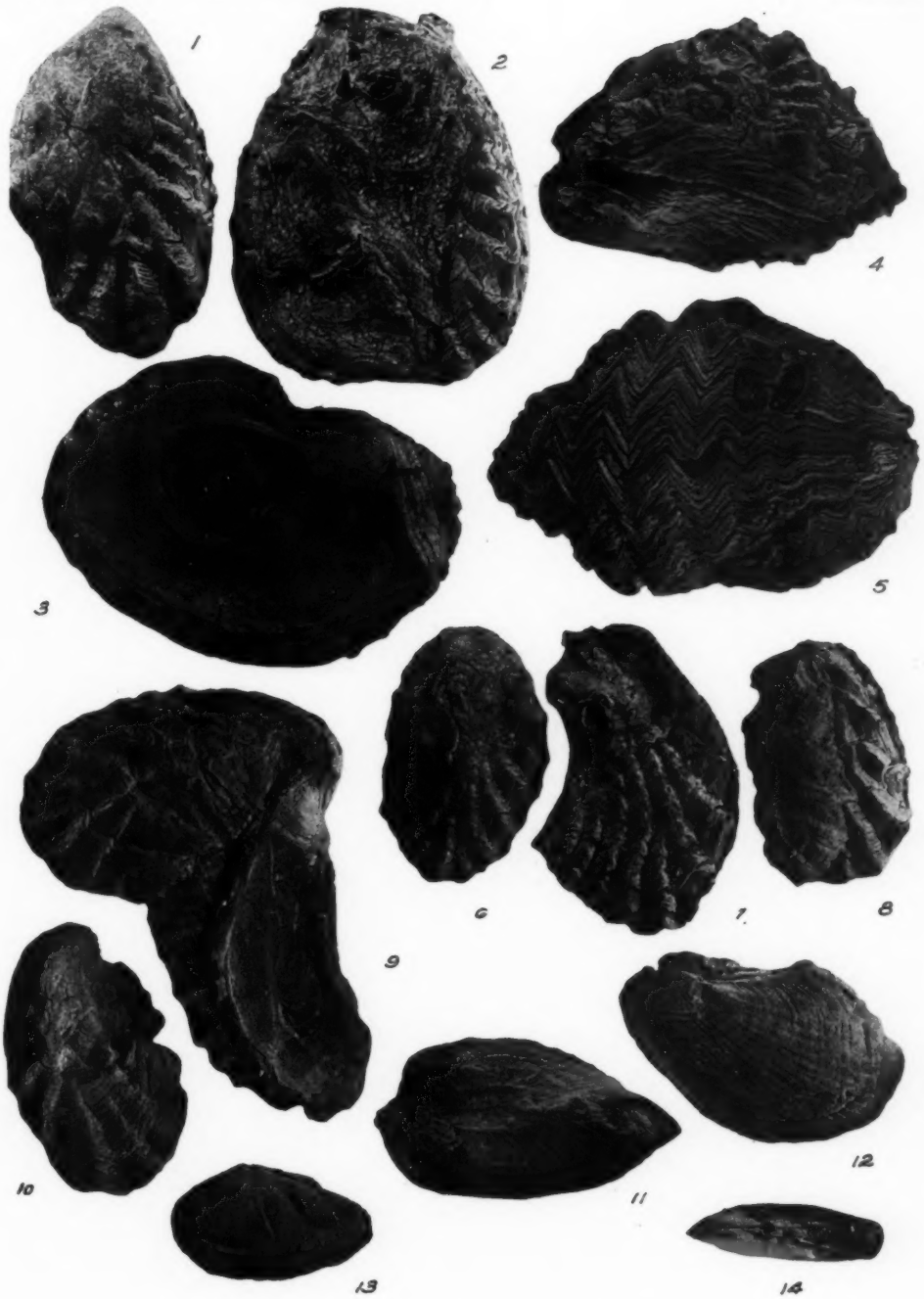
EXPLANATION OF PLATE 9

All figures natural size

FIGS. *1–10—Ostrea* (*Alectryonia*) *staufferi* Bergquist, n. sp. *1, 2*, Surface views of two right valves (paratypes). *3*, Internal view of a left valve (a paratype). *4*, Posterior view of holotype. *5*, Anterior view of holotype showing both valves in place. *6–8*, Surface views of small right valves (paratypes) showing differences in development of plications. *9*, A cluster of valves cemented together indicating how development of plications would be influenced by extent of attachment. *10*, Surface view of a small left valve (a paratype) showing small attachment scar and well-developed plications. All specimens from Coleraine formation, Arcturus mine, Marble, Minn. (p. 15)

11, 12—Pholadomya coloradoensis Stanton. Two views of an internal mold, showing left and dorsal portions; beaks and posterodorsal region broken; from Coleraine shale near Coleraine, Minn. (p. 20)

13, 14—Tellina calumetensis Bergquist, n. sp. Left and dorsal views of holotype, an internal mold from conglomerate of Coleraine formation, Hill Annex mine, Calumet, Minn. (p. 23)



Bergquist, Cretaceous Fossils

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the thick callus covered the entire shell and obscured the whorls; the ridge shown on the internal molds is the reflection of a prominent ridge on the outer lip of the wing; an oblique ridge passes from the top of the spire to initial portion of medial ridge and is continued downward onto the posterior canal.

Occurrence: In the conglomerate of the Coleraine formation, Hill Annex mine, Calumet, Minn.

APORRHAIS? sp.
Plate 11, figures 22, 23

A few small incomplete internal molds appear to belong to this genus. Body whorl large and contracted sharply below, periphery marked by a flattened band making an angulation above and below, but these merge on the preceding whorls to form a medial ridge. Inner lip of aperture excavated, outer lip slightly expanded. Whorls loosely apressed, angular above and below; columellar cavity large, two columellar folds indicated by faint grooves on inner side of whorls but disappear on body whorl a short distance from aperture. External surface marked by faint spiral ridges crossed by growth lines.

Occurrence: Northeast corner of Arcturus mine, Marble, Minn., and from south face of Hill Annex mine, Calumet, Minn.; occurring in the conglomerate of the Coleraine formation at both localities.

Figured specimens: Cat. No. 5053, Geol. Museum, Dept. of Geology, University of Minnesota.

ANCHURA GROUTI Bergquist, n. sp.
Plate 11, figures 2–5

Shell a little more than medium-sized; spire accuminate, whorls seven or more, slightly convex, closely appressed, increasing gradually in size; apex broken off on all specimens; suture slightly impressed; body whorl of shell convex, rounded in front and merged into a short anterior canal, which is broken on all specimens; inner aperture (seen from internal molds) broad, lenticular, notched in front for canal; outer lip thickened, expanded into a wide appendage, which on a large cotype extends for about 15 mm. and then curves upwards from the straight posterior margin into a long sharp, spurlike projection, which is divergent to the shell axis; tip about at height of second whorl above body whorl; posterior commissure of body whorl extended backward upon the penultimate; a deep groove occurs above midheight on inner wall of outer lip, extending from aperture upwards on posterior extension of lip; this is indicated by a sharp keel on internal molds and a pronounced ridge on squeeze from external molds.

Spire sculptured by curved axial ribs crossed by spiral ridges, giving a somewhat nodular effect; some external molds indicate that the axial ribs are lacking on the first three or four whorls and only a strong revolving line is seen along the suture (lack of axial ribs may in part be due to faulty preservation but seems to be quite prevalent); only spiral ridges occur on body whorl and these continue to deflection of wing, strongest development being on the midportion with a medial ridge continuing to tip of wing, the others are replaced by prominent growth lines from backward deflection of wing to the end.

Internal molds most common, having deeply impressed sutures where shell was greatly thickened; whorls not always appressed in early part and are convex outward, later whorls sometimes slightly flattened; surface smooth, internal thickening of shell apparently obliterated all external markings; columellar cavity broad and smooth.

Dimensions of largest squeeze from an external mold with anterior canal incomplete: altitude, 55 mm.; body whorl, about 20 mm. in diameter. Squeeze of wing: width from shell, 28 mm.; altitude, 35 mm. Dimensions of an internal mold in situ: altitude to base of body whorl, 50 mm.; maximum diameter across expanded lip, 43 mm. Altitude of a nearly complete internal mold, 52 mm.

Occurrence: In the conglomerate of the Coleraine formation, Hill Annex mine, Calumet, Minn., and Arcturus mine, Marble, Minn.

Cotypes: Internal and external molds, none complete; Cat. No. 5046, Geol. Museum, Dept. of Geology, University of Minnesota.

This species is named in honor of Dr. F. F. Grout, Department of Geology, University of Minnesota.

FUSUS SHUMARDI Hall and Meek

Fusus shumardi HALL and MEEK, 1856, Am. Acad. Arts and Sci. Mem., vol. 5, ser. 2, p. 391, pl. 3, fig. 6.
Fusus shumardi, WHITFIELD, 1880, Geol. Black Hills of Dakota, p. 424, pl. 12, figs. 7, 8.
Fusus shumardi, STANTON, 1893, U. S. Geol. Survey Bull. 106, p. 150, pl. 31, fig. 13.

Two external molds in the ferruginous sandstone from the Hill Annex mine furnished good squeezes showing the characteristic sculpturing of this form.

VOLUTODERMA (ROSTELLINDA) DALLI Stanton

Rostellites dalli STANTON, 1893, U. S. Geol. Survey Bull. 106, p. 156, pl. 33, figs. 11–13.

Squeezes made from external molds identify this species, although most are smaller than those described by Stanton. A number of internal molds were found. These show whorls to be either slightly flattened, with axial ridges, or gently convex and smooth; some show faint revolving lines on anterior part of body whorl; whorls are sharply rounded at the suture, which is deeply defined; the columellar cavity shows three deep grooves indicating the columellar folds that existed about midheight on the whorls of the shells.

Occurrence: In conglomerate of the Coleraine formation, Hill Annex mine, Calumet, Minn.

ACTAEON PROPINQUUS Stanton

Actaeon propinquus STANTON, 1893, U. S. Geol. Survey Bull. 106, p. 161, pl. 34, figs. 5–8.

A number of small internal molds appear to check quite well with this species, though some are a little larger and all seem to show fewer whorls. The revolving lines are plainly visible both on the molds and on impressions of the exterior surface, but the columellar fold is rarely seen and then only at the aperture of unbroken specimens.

Occurrence: In the conglomerate of the Coleraine formation, south face of Hill Annex mine, Calumet, Minn. (bed no. 9 of section, p. 7).

UNIDENTIFIED GASTROPOD
Plate 11, figure 1

Four incomplete internal molds show the following characteristics: whorls closely appressed, rapidly expanding, outer wall flattened producing an angulation posteriorly; surface showing either axial ridges or three spiral rows of elongate pits, the most posterior one being the deepest, with the anterior row least impressed; areas between the pits nodose or coalescing to form axial ridges with the pits indistinct except near the aperture, anterior portion of whorls smooth; inner wall marked posteriorly by a revolving furrow and by impressions of nodes of preceding whorl; columellar cavity large and marked by two deep grooves about midheight.

A fossil preserving body whorl and part of preceding whorl measures 35 mm. in height and about 24 mm. in maximum width.

Occurrence: In ferruginous grit of the Coleraine formation, Hill Annex mine, Calumet, Minn., and in the same material in the Arcturus mine, Marble, Minn.

EXPLANATION OF PLATE 10

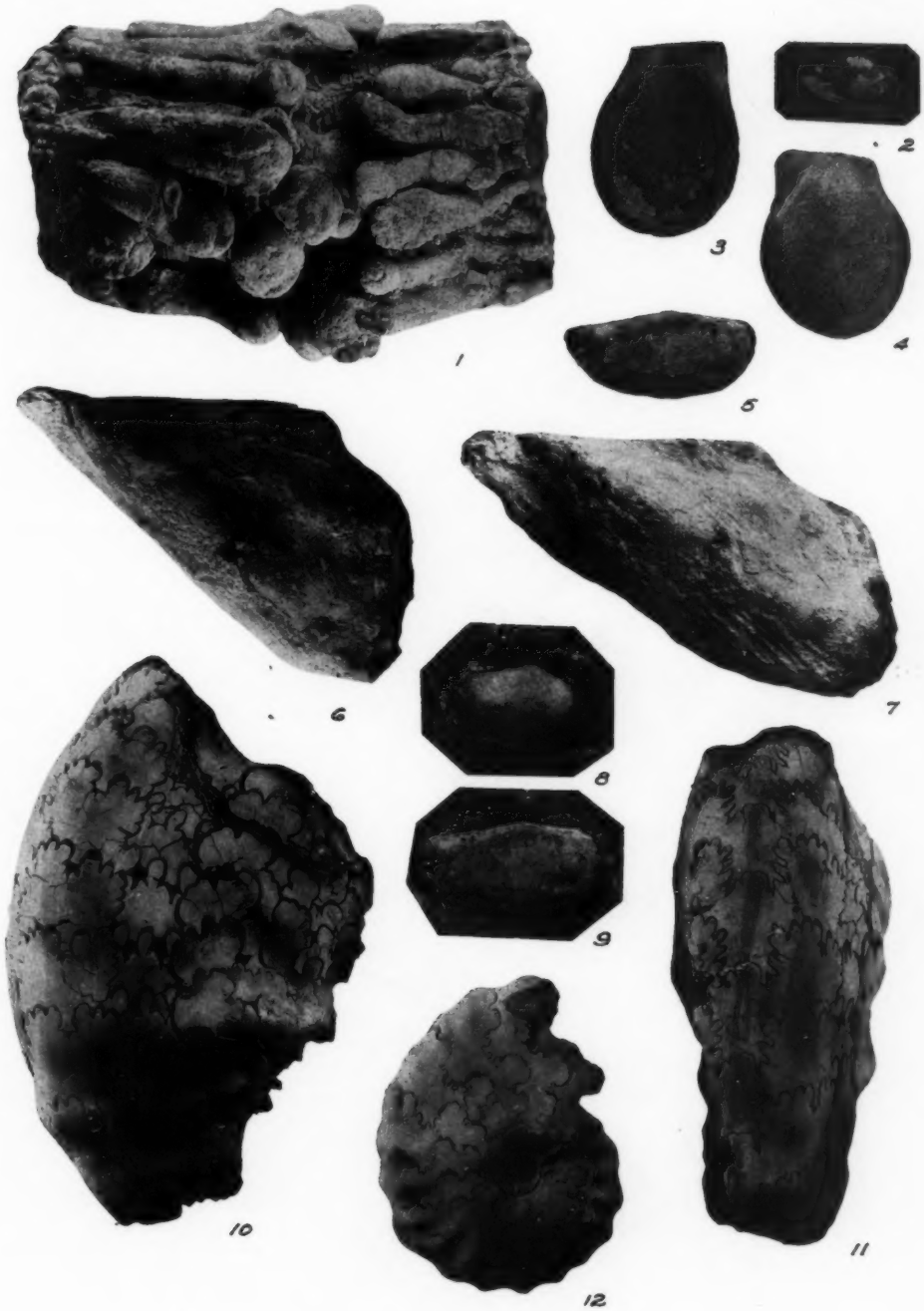
FIG. *1*—*Teredolites?* View, ×¾ of a mass of filled tubes of a wood-boring mollusk; wood almost entirely gone; From conglomerate of Coleraine formation, south face of Hill Annex mine, Calumet, Minn. (p. 24)

3, 4—*Pecten* (*Camptonectes*) *platessus* (White), var.? Views, ×1, of internal and external molds of two left valves. (p. 19)

2, 5, 8, 9—*Yoldia calumetensis* Bergquist, n. sp. Cotypes, ×1, all from Coleraine formation, Hill Annex mine, Calumet, Minn. *2*, Small specimen in conglomerate matrix showing some shell material on mold of left valve. *5, 9*, Two views of internal mold of a right valve; *9*, shows mold in conglomerate matrix. *8*, Internal mold of a left valve in conglomerate matrix; posterior portion broke. (p. 10)

6, 7—*Gervillia propleura* (Meek)? Two views, ×1, of left valve of an internal mold; *7*, shows outline; Coleraine formation, Hill Annex mine, Calumet, Minn. (p. 11)

10–12—*Metoicoceras* aff. *M. swallovi* (Shumard). *10*, Lateral view of internal mold of a broken medium-sized specimen, ×¾. *11*, Ventral views, ×¾, of same specimen. *12*, Internal mold of a small specimen, ×1. Specimens from conglomerate of Coleraine formation, Hill Annex mine, Calumet, Minn. (p. 30)



Bergquist, Cretaceous Fossils

Bergquist, Cretaceous Fossils

Figured specimen: Cat. No. 5055, Geol. Museum, Dept. of Geology, University of Minnesota.

SCAPHOPODA
DENTALIUM sp.
Plate 11, figure 15

Shell elongate, tapering, gently curved, circular to oval in cross section. Apical tip and apertural end broken away; external surface smooth, glazed, transverse growth lines faintly visible; internal surface smooth; aperture probably oval or circular. Largest individual measures 25 mm. in length, less than 1 mm. in diameter at apical end and 3 mm. in diameter at apertural end.

Only a few specimens were found, and none were complete. The shell substance is very chalky and is difficult to preserve. In appearance this form comes nearest to *D. pauperculum* Meek and Hayden from the Fox Hills and Pierre formations of the western interior, but it is much larger, only the smallest ones are about the same size as the western forms. It is probably a new species.

Occurrence: In the green shales of the Coleraine formation in the southeast corner of the Hill Annex mine at Calumet, Minn.

Figured specimen: Cat. No. 5057, Geol. Museum, Dept. of Geology, University of Minnesota.

CEPHALOPODA (AMMONOIDEA)
METACALYCOCERAS? sp.

Several fragmentary specimens, each representing a portion of a whorl of large ammonoids, could not be accurately identified but most closely resemble the genus *Metacalycoceras*. Material represents adult forms; whorls apparently loosely appressed; strong, smooth ribs continue from sides across venter with wide areas between. Suture partially shown on two specimens; siphonal lobe long, with long lobules; wide first lateral saddle, a symmetrical; first lateral lobe wide, as long as siphonal lobe, quadrifid; remainder not clearly shown.

Largest broken specimen showing part of last suture and a portion of living chamber is 10 inches along venter, 3½ inches in diameter laterally, and 4½ inches from ventral to dorsal areas; ribs 2½ inches apart on venter.

Occurrence: In the conglomerate of the Coleraine formation, Hill Annex mine, Calumet, Minn.

ACANTHOCERAS sp.

A 6-inch long piece of an internal mold of a robust form shows only a part of the living chamber with five ribs and a portion of the last suture. Ribs nearly straight, radiating, terminating in paired shoulder tubercles on each side; lateral tubercles only defined near

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EXPLANATION OF PLATE 11
All figures natural size.

FIG. *1—Gastropod.* View of an indeterminate broken internal mold, From conglomerate of Coleraine formation, Hill Annex mine, Calumet, Minn. (p. 28)

2–5—Anchura grouti Bergquist, n. sp. Cotypes; all from conglomerate of Coleraine formation, Hill Annex mine, Calumet, Minn. *2*, Wax squeeze of a small external mold lacking wing but preserving channel. *3*, Wax squeeze of an external mold, wing missing. *4*, Internal mold of a cotype, wing broken. *5*, Large internal mold in natural matrix, expanded wing showing. (p. 27)

6–9—Aporrhais (*Lispodesthes*) *nuptialis* (White). *6*, *8*, *9*, Internal molds showing whorls and part of expanded wing; *6*, in natural matrix, shows part of channel. *7*, Wax squeeze of an external mold, showing whorls were obscured by callus growth. Specimens from conglomerate of Coleraine formation, Hill Annex mine, Calumet, Minn. (p. 26)

10, 11, 16–19—Calliomphalus? colerainensis Bergquist, n. sp. *10*, *11*, Two views of a large internal mold. *16*, *17*, Apical views of small internal molds, the same shown in other views in *18*, *19*. From conglomerate of Coleraine formation, Arcturus mine, Marble, Minn. (p. 25)

12–14, 20, 21—Nerita? minnesotensis Bergquist, n. sp. Cotypes. *12–14*, Three views of an internal mold; denticle grooves visible in *13*, *14*. *20*, *21*, Small internal molds in natural matrix. Specimens from conglomerate of Coleraine formation, Hill Annex mine, Calumet, Minn. (p. 25)

15—Dentalium sp. Broken specimen from the shale of the Coleraine formation in the Hill Annex mine, Calumet, Minn. (p. 29)

22, 23—Aporrhais? sp. Views of broken internal molds of an indeterminate form, Coleraine formation, Arcturus mine, Marble, Minn. (p. 27)

base of living chamber, where ribs do not continue strong to the venter; ventral tubercles are somewhat elongate longitudinally. None of the shell material is preserved.

Occurrence: In the conglomerate of the Coleraine formation, Hill Annex mine, Calumet, Minn.

METOICOCERAS aff. M. SWALLOVI (Shumard)
Plate 10, figures 10–12

Ammonites swallovi SHUMARD, 1859, St. Louis Acad. Sci. Trans., vol. 1, p. 591.
Metoicoceras swallovi, HYATT, 1903, U. S. Geol. Survey Mon. 44, p. 118, pl. 11, figs. 7–24; pl. 13, figs. 1, 2; pl. 15, figs. 1–4.

Several incomplete specimens suggest a variety of *M. swallovi* or even a new species but for lack of more complete material is left with that species.

Small specimens representing young stages of growth show the lateral ridges and paired ventral nodes, but umbilical nodes are indistinct or lacking; the nodes in the row on the venter are elongated in the direction of the spiral. On older forms the second row becomes indistinct and lost, only the outer row showing as low knobs. A still later stage seems to be represented in which the living chamber has low lateral ridges, which nearly coalesce across the venter or terminate as low nodes with the venter becoming smooth and rounded near the aperture. Others show great compression of the shell, and the ribs are almost indistinct in the late stages.

The suturing differs from that of *M. swallovi* in having indentations on the saddles but not as complex as those of *M. whitei* Hyatt. It can be compared somewhat to *M. swallovi puercoensis* Herrick and Johnson (1900, p. 39, pl. 1, figs. 1–4) in its variations in shell structure but the sutures are more complex. The first lateral lobe is very broad, and on specimens representing old forms, where the sutures are close and almost overlap, the first lateral lobe is not as deeply indented and appears almost trifid or quadrifid in places.

Occurrence: In the conglomerate of the Coleraine formation, Hill Annex mine, Calumet, Minn.; Arcturus mine, Marble, Minn. and in the mines near Coleraine, Minn.

EPENGONOCERAS cf. E. DUMBLEI (Cragin)

Sphenodiscus dumblei CRAGIN, 1893, Texas Geol. Survey, 4th Ann. Rept., p. 243, pl. 44.
Metengonoceras dumblei, HYATT, 1903, U. S. Geol. Survey Mon. 44, pp. 185–188, pl. 27, figs. 3–14.
Epengonoceras dumblei, SPATH, 1924, Amm. Gault Folkestone, p. 508.

Only small fragments are available for comparison with the large form described. The sutures do not check entirely as to digitation of the lobes, but this may be because the Minnesota specimens represent young forms. Several impressions of the shell came from the shale horizon of the Hill Annex mine. These show the outline of the living chamber and a little thin pearly shell material.

Occurrence: Hill Annex mine, Calumet, Minn., in the green shales and in the conglomerate of the Coleraine formation; one specimen came from Coleraine, Minn.

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UPPER DEVONIAN BRYOZOA FROM NEW MEXICO

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ABSTRACT—A bryozoan fauna recently discovered in the San Andres Mountains, Sacramento Mountains, and the Mimbres Range of New Mexico includes 10 new species and three unnamed species. The strata containing it have been regarded as Upper Devonian upon physical grounds as well as upon the evidence supplied by various groups of fossils. At first it was thought that the Bryozoa furnished contradictory evidence as to age relationships in view of their distinct Middle Devonian aspect. A consideration, however, of the evolutionary trends displayed by the species studied has provided a possible explanation for this apparent disparity in age. For a relatively short period following the Middle Devonian, development of these forms seems to have been arrested and for a time to have remained static. As a result many Middle and Upper Devonian Bryozoa show a marked similarity. Certain groups reached racial old age, others had not yet approached their optimum development, while still other simpler forms do not appear to have been greatly affected by change in environment over long periods.

INTRODUCTION

TWO PALEONTOLOGICAL papers have been published that described Devonian faunas from New Mexico (Kindle 1909, and Stainbrook 1935). Neither of these investigations includes any detailed work upon the Bryozoa. The present paper deals entirely with that class of organisms. The material forming the basis of this study was collected by F. V. Stevenson, a student at the University of Chicago, from the localities in New Mexico listed below.

1. San Andres Canyon, San Andres Mountains, T. 19 S., R. 4 E.
2. Rhodes Canyon, San Andres Mountains, T. 13 S., R. 3 E.
3. On Bear Mountain Road, out of Silver City, 5.4 miles north of the corner of Atlantic and Alabama Streets.
4. Wilson's Ranch, on road between Hillsboro and Lake Valley.
5. Bear Mountain outcrop, near Silver City, SE ¼ NE ¼ sec. 10, T. 17 S., R. 15 W.
6. Chloride Flat, 1½ miles northwest of Silver City, center of NE ¼ sec. 32, T. 17 S., R. 14 W.
7. Deadman Canyon, San Andres Mountains, center of W ½ sec. 8, T. 17 S., R. 4 E.
8. Sly Gap, San Andrews Mountains, type section, sec. 25 T. 11 S., R. 5 E.
9. Alamo Canyon, Sacramento Mountains, due east of Alamogordo.

STRATIGRAPHIC RELATIONSHIPS

According to the stratigraphic studies of Stevenson (1941; 1942) three geological horizons are represented at these localities. In ascending order they are designated as the Canutillo, Sly Gap, and upper Percha shale formations. These subdivisions have apparently been established primarily upon sedimentary and faunal breaks and to a less degree upon superposition. Evidence on the whole would seem to favour a correlation with the early Upper Devonian and two stages of later Upper Devonian.

On the evidence provided by the Bryozoa alone such a correlation does not at first sight appear to be warranted. The general assemblage indicates a Middle Devonian rather than Upper Devonian age. Middle Devonian of Michigan, the Traverse, is particularly suggested.

It has been a former experience of the writer (Fritz, 1938, pp. 94, 95), however, that certain cryptostomatous bryozoan faunas from strata considered to be of Upper Devonian age are distinctly reminiscent of the Middle Devonian. A similar and even broader opinion has been more recently expressed by McNair (1942, pp. 343, 344).

It is to be regretted that the Bryozoa in this particular instance have not yielded species that would assist materially in assigning a definite age to the strata concerned the relationships of which have not been conclusively settled.

Since, however, very little work has been done on the Upper Devonian Bryozoa the systematic study of this new fauna is of considerable importance.

ANALYSIS OF FAUNA

Out of the comparatively small number of rather indifferently preserved specimens in the collection 13 species have been identified. Of these 10 are new and 3 belong to species which, owing to the fragmentary nature of the material, have only been generically determined. Among these forms 10 genera representative of four orders are included:

Ctenostomata.
Rhopalonaria.
Cyclostomata.
Fistulipora, 3 sp.
Trepostomata.
Eridotrypella.
Leptotrypa.
Leptotrypella, 2 sp.
Lioclema.
Cryptostomata.
Fenestrellina.
Ptiloporella.
Semicoscinium.
Sulcoretepora.

The table gives the geographic and geologic distribution of all the species as well as the possible age relationships. It will be noted that *Sulcoretepora anomalotruncata* may be a horizon marker in the shaly beds towards the top of the Canutillo formation (Nelson, 1940, p. 164) near the contact with the overlying Sly Gap. Here it appears to make up the bulk of several thin beds. It is apparently only rarely found in the heavier siltstones below. While the genus *Sulcoretepora* ranges from Devonian to Permian it is particularly characteristic of the Middle Devonian. Two species have recently been reported by McNair from the Upper Devonian (McNair 1942, p. 346). Though the present form represents a distinct species it does not appear to display characteristics that would distinctly separate it from the typical Middle Devonian forms as will be seen in the detailed description appearing later.

In the Sly Gap formation, which overlies the Canutillo and which is composed of shale, siltstone, and limestone, few Bryozoa of significance occur as far as the collections on hand are concerned. Their absence is somewhat of an anomaly, since brachiopods are numerous and varied. The two Bryozoa recognized belong to the genera *Fenestrellina* and *Lioclema*, the long range of which precludes their being of any great stratigraphic value in this particular instance.

The most prolific bryozoan fauna occurs in the uppermost subdivision, the upper Percha shale. In the 10 species identified there is little to be recorded that might not be noted in any average Middle Devonian assemblage. In view of this fact it would seem that evidence is not lacking to support the opinion that little intrinsic evolution

Species	Formation and Locality									Age
	Canutillo				Sly Gap	Upper Percha				
	1	2	7	9	8	3	4	5	6	
Eridotrypella intermedia, n. sp.						c	r	r		Still Later Upper Devonian
Fistulipora silverensis, n. sp.						r				
Fistulipora bearmontanensis, n. sp.								c		
Fistulipora sp. indet.							r			
Leptotrypa newmexicana, n. sp.							r			
Leptotrypella cavernosa, n. sp.								c		
Leptotrypella solitaria, n. sp.							r			
Ptiloporella australis, n. sp.							c		r	
Semicoscinium sp. indet.						r				
Rhopalonaria irregularis, n. sp.									r	
Fenestrellina, sp. indet					r					Later Upper Devonian
Lioclema slygapensis, n. sp.					r					
Sulcoretepora anomalotruncata, n. sp.	c	c	c	c						Early Upper Devonian

took place among the better known members of this phylum from Middle Devonian to the end of Upper Devonian time. In other words, evolution among the Bryozoa in the Upper Devonian in North America appears to have been temporarily arrested, their relationships being more with the older Devonian than with the Mississippian. In connection with this last statement there is one exception. The species *Rhopalonaria irregularis* from the upper Percha shale distinctly resembles *R. keokukensis* from the Keokuk of Iowa. Little weight is attached to this evidence, however, since remains of this ctenostomatous genus have been found in rocks as old as the Ordovician, and they have not shown during that long period any very marked tendency to change.

SYSTEMATIC DESCRIPTIONS

Phylum BRYOZOA Ehrenberg
Class ECTOPROCTA Nitsche
Order CTENOSTOMATA Busk
Family RHOPALONARIIDAE Nickles and Bassler
Genus RHOPALONARIA Ulrich

Ulrich's (1879, p. 26) description of the genus follows:

> Zoarium adnate, excavating the surface of the host so as to become usually about half embedded in it; consisting so far as known, of fusiform internodes or cells connected by extremely delicate tubular stolons, the whole arranged in a pinnate manner. Zooecia unknown, probably deciduous and developed by budding from a subcentrally suitated pore in the internodes.

Genotype.—Rhopalonaria venosa, Ulrich (1879, p. 26, pl. 7, figs. 24, 24a).

RHOPALONARIA IRREGULARIS Fritz, n. sp.
Plate 13, figure 1

Profusely covering the surface of a branching bryozoan, the identity of which has not been determined, is a well-defined species of *Rhopalonaria*. The characteristic feature of this form is the almost complete absence of the usual pinnate arrangement of the so-called branches. Instead, these structures are irregularly disposed, and in certain instances they tend to radiate.

The fusiform internodal segments have an average length of 0.5 mm. They are coarser and longer than the fine threadlike intervening stolons. In one part of the colony where a linear arrangement of the zoarial elements may be observed three internodes and two stolons occur in the space of 2 mm.

This species has its closest ally in the Mississippian form *Rhopalonaria keokukensis* (Ulrich and Bassler, 1903, p. 272) which in turn is related to *R. tenuis* Ulrich and Bassler from the Hamilton group of the Middle Devonian. Ulrich and Bassler have noted that the disparity in the ages of *R. keokukensis* and *R. tenuis* coupled with minor anatomical differences are the bases of specific differentiation. If the two occurred in the same formation they might be regarded as varieties of one species. We now see in this collection another remarkably similar form appearing at an intermediate horizon, which fact indicates the persistency of type in these simpler forms of Bryozoa in so far, at least, as their hard parts are concerned.

Holotype.—48900, Walker Museum, University of Chicago, Chicago, Ill.

Occurrence.—Upper Percha shale, locality 6, New Mexico.

Order CYCLOSTOMATA Busk
Family FISTULIPORIDAE Ulrich
Genus FISTULIPORA McCoy

The generic features are as follows:

> Zoarium massive, lamellate, ramose, parasitic, or free; under surface with a wrinkled epitheca; zooecia cylindrical or somewhat compressed, direct or almost so, thin-walled until near the surface and provided usually with a few diaphragms, and encircled by one or more series of vesicles; apertures subradially arranged about the maculae, ovoid, subtriangular, or pyriform, the lunarium more or less strongly developed; surface between apertures smooth or granular. (McCoy, 1850, p. 130.)

Genotype.—Fistulipora minor McCoy (1850, p. 130).

FISTULIPORA BEARMONTANENSIS Fritz, n. sp.
Plate 12, figures 1, 3

External features.—From the fragments examined the zoarium appears to have been lobate, giving rise to branches at irregular intervals. The largest fragment observed is 15 mm. by 20 mm. From this irregular mass is given off four branches, two round, two compressed. Surface is covered with rather

prominent monticules spaced from 3 mm. to 4 mm. apart measuring from centre to centre.

Tangential section.—Zooecia circular, five appearing in the space of 2 mm. A lunarium is present but it is not prominent. Near the surface the interzooecial tissue is finely granulose, below which many large irregular, angular mesopores surround the zooecia.

Vertical section.—The most striking feature of these sections is the abundant development of quite regular vesicular tissue separating the zooecia, in which diaphragms are present about two tube diameters apart in the axial region and approximately twice as close in the peripheral zone.

Holotype.—48901, Walker Museum, University of Chicago, Chicago, Ill.

Occurrence.—Upper Percha shale, common at locality 5, New Mexico.

FISTULIPORA SILVERENSIS Fritz, n. sp.
Plate 12, figures 7, 19

External features.—Zoarium consists of hollow branches, the observed diameter of which is 5 mm., thickness of the growth being 0.75 mm. The surface appears to be smooth except for a slight aggregation of mesopores into maculae.

Tangential section.—Zooecia are oval to tear-shaped. Measuring along the short axis six appear in 2 mm., while along the long axis five may be seen in a similar space. A distinct light-coloured rim is developed around each zooecium. This rim is less apparent on the narrower end of the zooecium. Between the zooecia coarse, angular, irregular mesopores abound. A lunarium is only slightly developed.

Vertical section.—The regular character of the vesicles in the connecting tissue is a striking characteristic of this species. The zooecia appear to be devoid of diaphragms at least in the outer region. They are practically all filled with sediment, which is an indication that they were originally empty except towards the base, where one diaphragm is present in certain tubes.

Holotype.—48902, Walker Museum, University of Chicago, Chicago, Ill.

Occurrence.—Upper Percha shale, rare at locality 3, New Mexico

FISTULIPORA sp. indet
Plate 12, figure 5

A very thin incrustation over the brachiopod *Camarotoechia endlichi* (Meek) is the only evidence of this particular species. Until more examples are found it has been considered inadvisable to assign a name to the species. The specimen provided material for only one thin section, which furnished the following information with regard to the internal structure:

Zooecia viewed from the tangential aspect number approximately six in 2 mm. They are oval structures provided with a well-marked lunarium. Near the surface the space between the zooecia appears to have been decidedly granular. Deeper in the section large angular mesospores are well developed. Only a hint of the structure in vertical section is seen. It shows irregularly developed vesicular tissue between the zooecia, the zooecia themselves being provided with an occasional diaphragm.

Figured specimen.—48903, Walker Museum, University of Chicago, Chicago, Ill.

Occurrence.—Upper Percha shale, rare at locality 4, New Mexico.

Order TREPOSTOMATA Ulrich

It has been pointed out by Duncan (1939, pp. 182, 183) in her admirable discussion of the taxonomy and relationships of the Devonian Trepostomata of Michigan that two natural organic groups appear to be present —one senescent, the other adolescent.

The first group appears to be related to families that reached their optimum development earlier in the Palaeozoic, namely the Prasoporidae, Heterotrypidae, Halloporidae, Amplexoporidae, and Trematoporidae. Though resemblances to these early families may be apparent, Devonian representatives are distinguished by the presence of laminated, intermittently thickened walls, the lack of mesopores, and other accompanying features. Such characters indicate an excess secretion of calcium carbonate, which might be regarded as the particular type of overspecialization of structure manifested by these organic groups prior to their final extinction.

The second group, which includes more primitive forms, represents in all probability

adolescent types possibly ancestral to the later Palaeozoic senile Batostomellidae.

In this New Mexican fauna two families of Trepostomata are represented, the Heterotrypidae and the Batostomellidae. Included in the Heterotrypidae are at least four distinct species. Three of these species are closely related but each presents a problem in connection with its generic relationships. The fourth form is an incrusting *Leptotrypa*. Of the Batostomellidae one new species of the comparatively simple genus *Lioclema* occurs.

The three closely related heterotrypid species of uncertain generic relationships just referred to belong to the first of the above mentioned natural groups. They exhibit features characteristic of *Eridotrypella*, *Eridocampylus*, and *Leptotrypella*. One is herein assigned tentatively to the genus *Eridotrypella*, two to the genus *Leptotrypella*. In the descriptions of these species that follow a discussion will be included with regard to their individual peculiarities.

Family Heterotrypidae Ulrich

Judging from the relatively small number of species represented and from the uncertainty surrounding the generic identifications as noted in the following study it is reasonable to believe that the family Heterotrypidae has undergone a great change since earlier Palaeozoic times, it reached the peak of its development both specifically and numerically. In the late Devonian it was reduced to a position of insignificance. Accompanying this stage in its life history, the tendency on the part of the individual animal to secrete an abundance of lime appears to have become more and more a fixed habit. Consequently, considerable generic differentiation may have been caused by the variability of the limy deposits. With this seemingly uncontrolled tendency at work, the organisms became practically entombed, a circumstance which in all probability led to the ultimate extinction of the family group (Lang, 1919, p. 107).

It is significant that this new fauna shows similar trends to those recently noted in the Michigan Basin. The recognition of such details of structure is singularly important and should assist materially in future stratigraphic work.

Genus Eridotrypella Duncan

The description of the genus is as follows:

> Zoarium ramose. Wall structure heterotrypid-amalgamate; transverse rows of granules well defined. Walls thin, usually crenulated in immature region, gradually thickened from beginning of mature zone to surface. Zooecia oblique, slightly bent toward surface in mature zone. Diaphragms absent in immature zone, several closely arranged in early mature zone of each zooecium, usually absent near periphery. Mesopores absent. Acanthopores granular. (Duncan, 1939, p. 210).

Genotype.—Batostomella obliqua Ulrich (1890, p. 433, pl. 46, figs. 2–2c).

Eridotrypella intermedia Fritz, n. sp.
Plate 12, figures 2, 4, 18

External features.—Zoarium ramose. The branches, which tend to be compressed, measure from 5 mm. to 10 mm. in diameter. Surface covered with conspicuous, low, rounded monticules spaced about 3 mm. apart measuring from centre to centre. Monticules consist of zooecia larger than the ordinary.

Tangential section.—Zooecia polygonal, averaging eight in 2 mm.—those in the monticules about six in 2 mm. An occasional small tube present in monticules. Heterotrypid wall structure distinct. Transverse rows of granular acanthopores are well developed in the median light-coloured band. Some of the largest of them are quite regularly arranged about the zooecia. In addition to the granules large acanthopores of varying sizes, some unusually large, occupy many of the zooecial angles. A few inflect the walls. The larger acanthopores appear to be made of concentrically laminated tissue with a solid centre. Bordering the median light-coloured band on either side is concentrically laminated tissue. Zooecial apertures greatly restricted in most instances by the development of this laminated tissue, which gives them an infundibular shape. This condition is particularly noticeable in the thicker parts of the sections, which permit a three dimensional view.

Vertical section.—Zooecia thin-walled in the axial region, straight or slightly crenlated. Small periodic thickenings reminiscent of the genus *Stigmatella* observed in some sections. Diaphragms practically absent in axial portion. Zooecial tubes bent towards

surface in transition zone but becoming a little more direct in mature zone. Diaphragms quite numerous in transition zone, where they are straight or oblique; mostly absent in mature zone. Walls become greatly thickened in the mature region, particularly in the outer part, with very irregular, somewhat beadlike deposits of laminated tissue. Spurlike projections of this tissue, simulating heterophragms, extend partly across the tubes. Similar structures have been noted in the genus *Stenoporella* Bassler (1936, p. 157) and in *Microcampylus* (Duncan, 1939, p. 253) but other features present do not suggest either of these genera.

Remarks.—This form is one which demonstrates very clearly the intergrading of the species comprising the genera *Eridotrypella* and *Eridocampylus*. Here we have a species possessing the general features of each of these genera. The peculiarly irregular nature of the mural deposits of the mature zone, however, is not actually characteristic of either. Since the spurlike projections are not true heterophragms the genus *Eridocampylus* is precluded. It appears to fit better in the genus *Eridotrypella* but may be regarded as constituting a link between these two closely related generic groups.

Among the described species of *Eridotrypella*, affinities are recognized with *E. spinifera* Duncan and *E. granosa* Duncan. Aside from the thick irregular walls, *E. intermedia* may be distinguished by its abundance of larger acanthopores and the presence of a few diaphragms in the axial region.

Holotype.—48904, Walker Museum, University of Chicago, Chicago, Ill.

Occurrence.—Upper Percha shale, common at locality 3; occurs more rarely at 4 and 5, New Mexico.

Genus LEPTOTRYPELLA Vinassa de Regny (1920, p. 222)

Duncan's more complete emended description (1939, p. 223) follows:

Zoarium usually ramose. Walls moderately thick, nongranular; laminated zooecial deposits separated by amalgamate medial band. Zooecia polygonal. Diaphragms complete, usually numerous in mature zone, often thick and merging into laminated wall tissue. Mesopores absent; minute zooecia occasionally present. Acanthopores well defined, generally numerous, but nearly absent in a few species, always present and usually stronger within groups of larger zooecia or monticules.

Genotype.—*Chaetetes barrandi* Nicholson (1874, p. 57, pl. 4, fig. 7c).

LEPTOTRYPELLA SOLITARIA Fritz, n. sp. Plate 12, figures 10, 16

External features.—Only one specimen of this species was found in the collection. There was just sufficient material for two sections. It is a small branching form, observed zoarium less than 5 mm. in diameter. Surface smooth.

Tangential section.—Zooecia polygonal,

EXPLANATION OF PLATE 12

FIGS. *1, 3—Fistulipora bearmontanensis* Fritz, n. sp. Holotype, Walker Mus., Univ. Chicago, no. 48901, ×15. *1*, Vertical section; *3*, tangential section. (p. 33)

2, 4, 18—Eridotrypella intermedia Fritz, n. sp. Holotype, Walker Mus., Univ. Chicago, no. 48904, ×15. *2*, Vertical section; *4, 18*, Tangential sections. (p. 35)

5—Fistulipora sp. indet. Walker Mus., Univ. Chicago, no. 48903. Tangential section, ×15. (p. 34)

6, 13—Leptotrypella cavernosa Fritz, n. sp. Walker Mus., Univ. Chicago, no. 48908. *6*, Paratype, tangential section, ×15; *13*, holotype, vertical section, ×15. (p. 37)

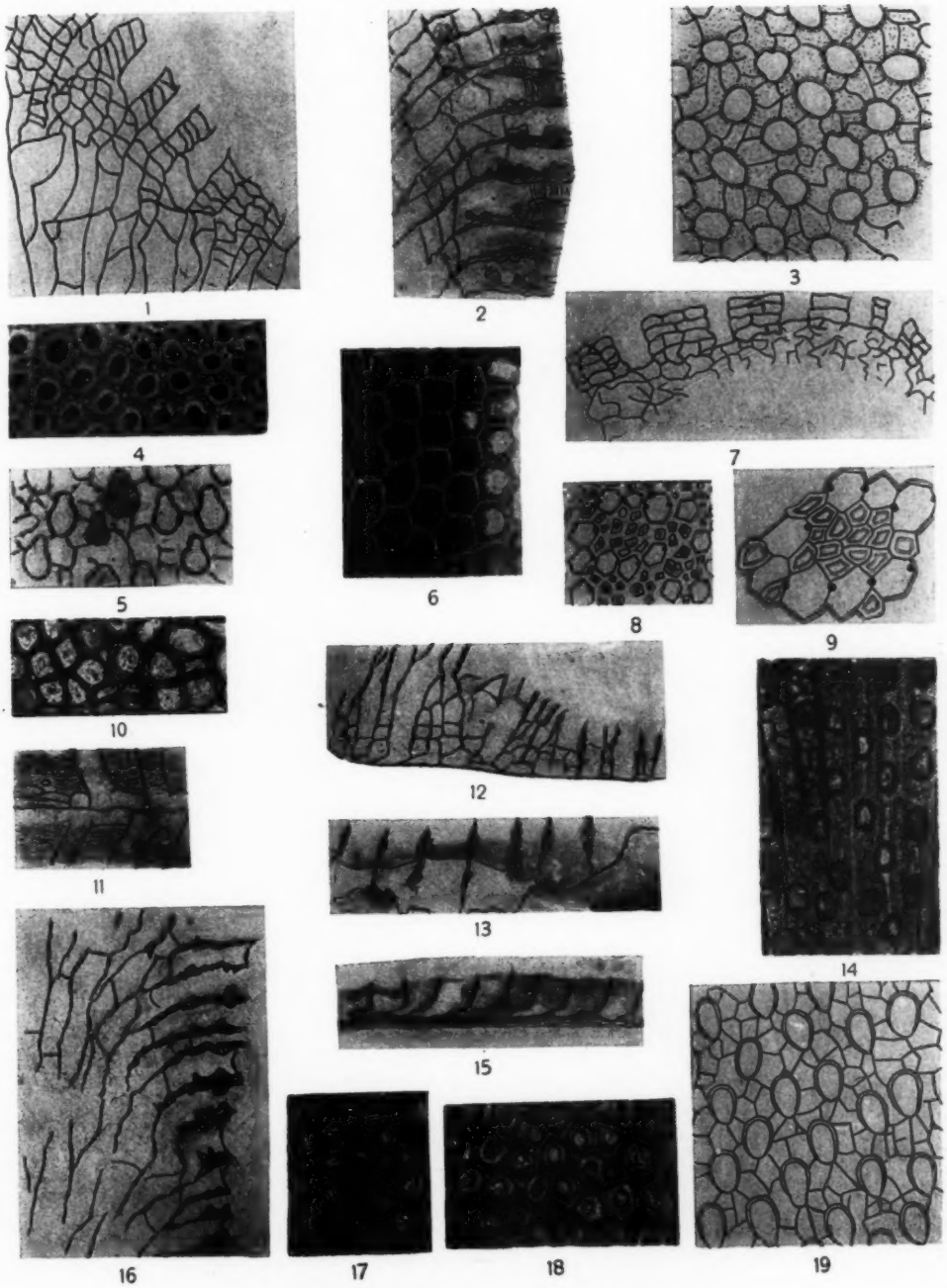
7, 19—Fistulipora silverensis Fritz, n. sp. Holotype, Walker Mus., Univ. Chicago, no. 48902, ×15. *7*, Vertical section; *19*, tangential section. (p. 34)

8, 9, 12—Lioclema slygapensis Fritz, n. sp. Cotype, Walker Mus., Univ. Chicago, no. 48910. *8*, Tangential section, ×15; *9*, part of *8*, ×22½; *12*, Vertical section, ×15. (p. 38)

10, 16—Leptotrypella solitaria Fritz, n. sp. Holotype, Walker Mus., Univ. Chicago, no. 48907, ×15. *10*, Tangential section; *16*, Vertical section. (p. 36)

11, 14—Sulcoretepora anomalotruncata Fritz, n. sp. Cotype, Walker Mus., Univ. Chicago, no. 48915, ×15. *11*, Vertical section; *14*, Tangential section. (p. 40)

15, 17—Leptotrypa newmexicana Fritz, n. sp. Holotype, Walker Mus., Univ. Chicago, no. 48909, ×15. *15*, Vertical section; *17*, Tangential section. (p. 38)



Fritz, Upper Devonian Bryozoa

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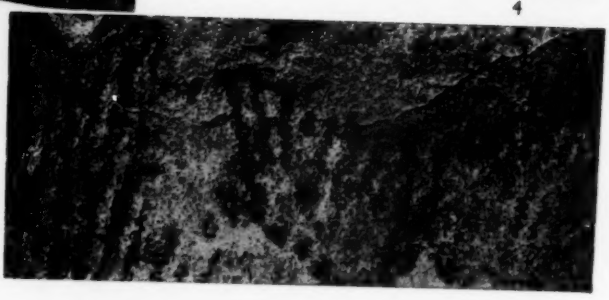

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Fritz, Upper Devonian Bryozoa

irregular in size, about eight in 2 mm. Few small tubes interspersed among the regular zooecia. Medial light band very narrow, scarcely discernible for the most part and not granular. Laminated zooecial deposits well defined. Acanthopores of moderate size but not abundant; when present situated in the angles of the zooecia.

Vertical section.—Zooecial walls erect, thin-walled, and not crenulate, or only slightly so in the axial region. Zooecial tubes bent abruptly from the transition zone to the surface. Walls irregularly thickened, though not excessively, in the mature region where rounded and spurlike outgrowths project into the zooecial tubes. As in *Eridotrypella intermedia*, these mural outgrowths can scarcely be regarded as true heterophragms, though in this particular instance the resemblance to such structures is somewhat more marked. Diaphragms sparsely developed in the axial zone, slightly more numerous in the transitional zone, absent in outer mature region.

Remarks.—Here again we see a peculiar combination of characters. Typical *Leptotrypella* structure is clearly shown aside from the presence of the heterophragm-like elements, which suggest the genus *Eridocampylus*. The absence, however, of the granular medial amalgamate band excludes that genus as a possibility. None of the described species of *Leptotrypella* show very close relationships with this new form. In tangential section *L. varia* is comparable in regard to the narrow light band, acanthopores, and laminated tissue, but groups of larger zooecia distinguish that form. *Eridotrypella ulrichi* in vertical section is remotely similar.

Holotype.—48907, Walker Museum, University of Chicago, Chicago, Ill.

Occurrence.—Upper Percha shale, rare at locality 4, New Mexico.

LEPTOTRYPELLA CAVERNOSA Fritz, n. sp.
Plate 12, figures 6, 13

External features.—Zoarium forming hollow branches, sometimes incrusting. Thickness not exceeding 0.5 mm. Surface with small rather sharp monticules in which zooecia are larger than the ordinary.

Tangential section.—Zooecia polygonal, commonly hexagonal or pentagonal but often rhombic, six to seven in 2 mm. Medial light band particularly clear. Laminated deposits present but not abundantly developed No mesopores nor small tubes observed. Acanthopores practically absent.

Vertical section.—Zooecia slightly oblique; walls thickened irregularly and gradually from immature to mature region; edges hirsute. Diaphragms practically absent, possibly one in a few of the zooecia.

Remarks.—The hollow branching and incrusting type of zoarium is not hitherto recorded for the genus *Leptotrypella*. The lack of acanthopores and the small number of diaphragms also are not typical. The strongest evidence for thus placing this species is the very well marked amalgamate nongranular band and the presence of laminated tissue.

Cotypes (3).—48908, Walker Museum, University of Chicago, Chicago, Ill.

Occurrence.—Upper Percha shale, common at locality 5, New Mexico.

Genus LEPTOTRYPA Ulrich

The fourth heterotrypid species represented in the collection belongs to the genus *Leptotrypa* Ulrich, the generic characteristics of which follow:

> Heterotrypidæ with the zoarium thin, evenly spread, parasitic expansions with thin-walled, polygonal zooecia, no mesopores, few diaphragms, and very small acanthopores which are never abundant. (Ulrich, 1883, p. 158.)

EXPLANATION OF PLATE 13

FIG. *1*—*Rhopalonaria irregularis* Fritz, n. sp. Holotype, Walker Museum, University of Chicago, no. 48900, ×5. (p. 33)

2—*Semicoscinium* sp. indet. Walker Museum, University of Chicago, no. 48913, ×5. (p. 40)

3—*Sulcoretepora anomalotruncata*, Fritz, n. sp. Cotype, split across median septum, Walker Museum, University of Chicago, no. 48914, ×1. (p. 40)

4—*Ptiloporella australis* Fritz, n. sp. Holotype, Walker Museum, University of Chicago, no. 48912, ×1. (p. 39)

5—*Fenestrellina* sp. indet. Walker Museum, University of Chicago, no. 48911, ×5. (p. 39)

Genotype.—Leptotrypa minima Ulrich (1883, p. 159, pl. 6, figs. 2, 2b).

LEPTOTRYPA NEWMEXICANA Fritz, n. sp.
Plate 12, figures 15, 17

External features.—Zoarium forming a very thin incrustation over the brachiopod *Camarotoechia endlichi* (Meek). Observed thickness not more than 0.4 mm. Surface destitute of maculae, monticules, or special groups of Zooecia.

Tangential section.—Zooecia irregularly polygonal, commonly hexagonal but occasionally quadrate, approximately 10 in 2 mm. Walls thin. Mesopores absent, but a few small zooecia occur. Acanthopores small but well defined, situated chiefly in the angles of the tubes. Walls only slightly granular.

Vertical section.—Zooecia at first thin-walled and oblique, forming an angle of about 30° with host. They then make an abrupt turn, opening directly at surface. Walls noticeably thickened in mature zone. Diaphragms appear to be absent.

Remarks.—This well-marked little species resembles *Leptotrypa nicholsoni* Duncan, the chief differences being the lack of distinctly granular walls, the attitude of the zooecia as seen in vertical section, and the absence of diaphragms.

Holotype.—48909, Walker Museum, University of Chicago, Chicago, Ill.

Occurrence.—Upper Percha shale, rare at locality 4, New Mexico.

Family BATOSTEMELLIDAE

The remaining family of Trepostomata to be considered here is the Batostomellidae. Representatives of this family are known from the Ordovician and Silurian though not until the Devonian are they sufficiently numerous to be regarded as characteristic fossils. They reach their maximum development in the Carboniferous and decline in the Permian. It was hoped that the present material would furnish some examples of the newly described Michigan batostomellids, but up to the present only one species has been identified, and it belongs to the long-lived, relatively unspecialized genus *Lioclema* Ulrich (1882, p. 154) a description of which is given herewith:

Genus LIOCLEMA Ulrich

Zoarium ramose, lamellar, subglobose, or incrusting; surface frequently exhibiting distinct monticules or maculae; zooecia with subcircular or irregular petaloid apertures, separated by abundant angular mesopores, which in some species are open at the surface, in others closed; diaphragms few in zooecia, abundant, and sometimes crowded in the mesopores; acanthopores numerous and strong in the typical species, small and inconspicuous in others. (Ulrich, 1882, p. 154.)

Genotype.—Callopora punctata Hall (1858, p. 653).

LIOCLEMA SLYGAPENSIS Fritz, n. sp.
Plate 12, figures 8, 9, 12

External features.—Zoarium an irregularly contorted expansion attaining a thickness of 1.25 mm. Surface with prominent irregularly spaced monticules. Numerous mesopores inconspicuously assembled into small groups.

Tangential section.—Zooecia subpolygonal or subcircular, 0.15 to 0.25 mm. in diameter, an average of seven in 2 mm., usually separated by mesopores but occasionally contiguous. Mesopores abundant, polygonal or rounded, of varying size, those in the ill-defined patches tending to be larger and more uniform than those which regularly separate the zooecia. Deposits lining mesopores more noticeable than those in the zooecia. Acanthopores not numerous but clearly defined and of moderate size, two or, at the most, three situated in the zooecial walls, occasionally inflecting them but never rendering the zooecia petaloid.

Vertical section.—Zooecia tend to be prone or vertical to begin with, though this feature is not always evidenced, later direct. Walls, particularly of mesopores, thicken gradually from the short immature zone ultimately becoming appreciably thickened. Diaphragms in early portion of mesopores from half a tube to a tube diameter apart, not as numerous in mature zone, practically absent in zooecia.

Remarks.—In *Lioclema slygapensis* we have a species of the *L. incompositum—traversense—passitabulatum* group, all of which are described by Duncan. Its most characteristic and distinguishing features are the small number of diaphragms in both zooecia and mesopores, and lack of granular walls.

Occurrence.—Sly Gap formation, rare at locality 8, San Andres Mountains, New Mexico.

Cotypes (2).—48910, Walker Museum, University of Chicago, Chicago, Ill.

Order CRYPTOSTOMATA Vine
Family FENESTRELLINIDAE Bassler
Genus FENESTRELLINA d'Orbigny

D'Orbigny's description of the genus (1849, p. 501) follows:

Ce sont des *Fenestrella*, pourvues de pores intermédiaires très-espacés sur la coté qui sépare les deux rangées de cellules. Les 4 espèces de ce genre perdusont de l'étage carbonifèrien.

Genotype.—*Fenestrella crassa* McCoy (1844, p. 201, pl. 29, fig. 1).

FENESTRELLINA sp. indet.
Plate 13, figure 5

With a single specimen exposing only the obverse side of the zoarium the establishment of a new species for this example of *Fenestrellina* is not warranted. The brief description that follows will perhaps assist in recognizing the form should it be met in further collections from the area.

External features.—Contorted fragments of the zoarium cover a piece of siltstone measuring 35 mm. by 10 mm. Branches parallel, subangular, coarse, 0.3 mm. wide, eight to nine in 5 mm., bifurcation at 4 mm. intervals, carina insignificant, possibly sinuous and with small nodes. Zooecia with prominent peristomes, 20 to 22 in 5 mm. indenting the margins of the branches. Fenestrules rectangular, four zooecia to the length of a fenestrule. Dissepiments about half the width of the branches and comparatively long.

This species is distinguished by its coarse branches, the edges of which are crenulated by the prominent, indenting zooecia. The paucity of material does not permit an adequate comparison with previously described forms. Among the numerous species described by Deiss (1932, pp. 237–247) affiliated forms might be expected.

Figured specimen.—48911, Walker Museum, University of Chicago, Chicago, Ill.

Occurrence.—Sly Gap formation, rare at locality 8, New Mexico.

Genus PTILOPORELIA Hall

The generic description is given herewith:

Zoarium a fenestrated funnel-shaped expansion; branches of two sizes, the smaller or secondary branches proceeding laterally from the larger or primary ones, either from one or both sides; as the frond expands, other large branches proceed from the primary ones, this process continuing during the growth of the frond; apertures in two rows separated by a carina; the carinae of the primary branches more prominent than those of the secondary branches. (Hall, 1885, p. 36.)

Genotype.—*Fenestella laticrescens* Hall and Simpson (1897, p. 171).

PTILOPORELLA AUSTRALIS Fritz, n. sp.
Plate 13, figure 4

External features.—Zoarium infundibuliform with convolutions particularly well shown towards the periphery. Observed width 65 mm., height between 40 mm. and 45 mm.

Reverse.—Both primary and secondary branches present. The primaries, which stand out prominently, commence at the base of the zoarium and do not appear to increase appreciably in size. They are distinctly angular and about twice the width of the secondaries. At more or less regular intervals of from 8 to 10 mm. new secondaries develop and branch off from one or other of the sides of the primaries. In this way expansion of the colony takes place. Secondaries somewhat angular and marked by faint longitudinal lines. They average five in 2 mm. measuring transversely. Dissepiments about the same width as the secondaries. Fenestrules rectangular in shape, three in 2 mm. measuring across the zoarium while four occupy the same space vertically.

Obverse.—This side not actually exposed, but where the reverse side has weathered the general nature of the obverse can be detected. Zooecia in two rows, large, three to length of a fenestrule, alternately arranged on either side of a sinuous, median carina Fenestrules oval.

Remarks.—The genus *Ptiloporella*, although known from both the Silurian and Devonian, is represented by relatively few species. In the collections under study it is the most abundant of the lacy cryptostomes. It is absent in the Michigan basin according to the published records. Among the locali-

ties listed for species from the Middle Devonian are Falls of the Ohio, in Kentucky, and Walpole, Ontario. No species appear to be recorded from the Upper Devonian.

Holotype.—48912, Walker Museum, University of Chicago, Chicago, Ill.

Occurrence.—Upper Percha shale, common at locality 4; rare at locality 6, New Mexico.

Genus SEMICOSCINIUM Prout (1859, p. 443)

A description of the genus follows:

Zoaria funnel-shaped, poriferous on the outer side. Dissepiments wide, very short, the branches appearing on the non-celluliferous side to anastomose. Here also, the fenestrules are subrhomboidal or rounded. Zooecia in two ranges. Median keel very high and more or less expanded at the summit. (Nickles and Bassler, 1900, p. 28.)

Genotype.—Semicoscinium rhomboideum Prout (1859, p. 443, pl. XVII, 1–1f).

SEMICOSCINIUM sp. indet
Plate 13, figure 2

One fragmentary specimen is assigned tentatively to this genus. The limited nature of the material, however, does not warrant the establishment of a new species. Its chief features are being recorded here in order that the form may be more readily identified should further specimens be later acquired.

External features.—Zoarium known from flattened fragments exposing the obverse side only. Branches parallel, five in 2 mm., bifurcation interval not clear but in one instance 3 mm. Fenestrules elliptical, four in 3 mm. measuring longitudinally, not inflected by zooecial apertures. Dissepiments 0.3 mm. long, half as wide as branches, broadest where they join branch. Zooecia large, apertures circular, no distinct peristome, laterally disposed, three to length of a fenestrule. Carina comparatively thick and only moderately elevated, apparently straight, and not noticeably expanded at summit. Specimen worn so that detail of structure is not definite.

Remarks.—None of the later Devonian species resemble this form to any marked degree. Its closest relative appears to be *S. thyene* (Hall) from the Lower Devonian (Helderberg) of New York.

Examples of this genus are uncommon in the Upper Devonian. McNair's (1942, p. 345) species *S. flabellum* is distinctly different from the present form but agrees in having the summit of the carina unexpanded.

Figured specimen.—48913, Walker Museum, University of Chicago, Chicago, Ill.

Occurrence.—Upper Percha shale, locality 3, New Mexico.

Genus SULCORETEPORA d'Orbigny

The original description follows:

Cellules placées par lignes dans des sillons longitudinaux, et d'un seul côté de branches simples déprimées, striées en long du côté opposé aux cellules. Les deux espèces connues de ce genre peru sont spéciales a l'étage carboniferien. (D'Orbigny, 1849, p. 501.)

Genotype.—Flustra parallela Phillips (1836, pl. I, figs. 47, 48).

SULCORETEPORA ANOMALOTRUNCATA Fritz, n. sp.
Plate 12, figure 11, 14;
plate 13, figure 3

External features.—Zoarium smooth, bifoliate, ribbonlike, and dichotomously branched. Branches with a diameter of 3 mm. to 6 mm. dividing at intervals of 15 mm. to 20 mm. Zooecia arranged in linear series separated by prominent longitudinal ridges. From 10 to 20 rows of zooecia present on the branches. Only a very narrow, nonporiferous margin occurs.

Tangential section.—Zooecia eliptical, opening almost directly to surface, peristome prominent and fairly wide. Lunarium present, forming a noticeable truncation on zooecium. Lunarium not on side of aperture nearest margin of branch as noted in the generic description but on lower margin of zooecium. Interspaces between apertures and longitudinal ridges finely granulated.

Vertical section.—Zooecia boot-shaped, approximately 1 mm. long, vestibule occupying two-thirds of the length. Superior hemiseptum present. Vesicular tissue occupies space between vestibular portion of the zooecia. At the surface the vesicles become filled with a more or less solid calcareous deposit.

Remarks.—Although the genus *Sulcoretepora* ranges through the Devonian and Permian it is particularly characteristic of the Middle Devonian. The present species is one of the most significant in the collection

owing to its abundant development at the top of the Canutillo formation where it serves as a definite horizon marker.

McNair (1942, p. 346) in his recent studies on Upper Devonian Bryozoa describes two species, *Sulcoretepora willardi* and *S. chadwicki*. From the former *S. anomalotruncata* differs mainly in the practical absence of much larger marginal apertures; from the latter in the presence of interzooecial vesicular tissue. From each of these species it differs in the possession of a peculiar lunarium, which truncates the lower margin of the zooecia. The affinities of this new species would appear to be with the Middle rather than the Upper Devonian forms as they are at present known. Of the numerous representatives of the genus described by McNair (1937, pp. 137–145) from the Middle Devonian of Michigan *S. obliqua* and *S. alternata* bear the closest resemblance to this New Mexican form. The nature and position of the lunarium, features which appear to be constant in all the specimens examined, distinguish this new species.

Cotypes (2).—48914; 48915, Walker Museum, University of Chicago, Chicago, Ill.

Occurrence.—Canutillo formation, common at localities 1, 2, 7, 9, New Mexico.

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PARAFAVOSITES AND SIMILAR TABULATE CORALS

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During the investigation of some Silurian corals submitted for study by Dr. I. P. Tolmachoff of Carnegie Museum, who collected them during his expedition to the Khatanga area of the Government of Yeniseisk, Siberia,[1] while a member of the Russian Geological Survey, the writer identified five new species of the same generic type as the interesting Ellesmereland favositoid *Parallelopora* (now *Parafavosites*) *favositiformis* Holtedahl, 1914. The study of these species led to a search of the literature for possibly related forms, which resulted in the conclusion that the Silurian and Devonian genera, *Boreaster* Lambe, 1906, *Gephuropora* Etheridge, 1920, *Plasmadictyon* Wilson, 1926, *Hattonia* Jones, 1927, and *Sapporipora* Ozaki, 1934, may all belong to the Favositidae. As each requires further study, attention is here called to these genera from such widely scattered parts of the world by giving a resumé of the knowledge concerning them.

In the writer's opinion, the corallum and the surface of such compound corals are seldom worthy of illustration, and photographs of thin sections of the interior are equally of little value because they usually show the calcite and other nonessential features more plainly than the real structure. Therefore, in the present paper drawings of the internal structure have been substituted. These have been prepared from photographs by carefully inking in the coral structure and then bleaching out the background. Although thin sections are a necessity in the study of massive corals, a species once clearly illustrated can usually be recognized under the lens from smoothed surfaces slightly etched with acid. In many descriptions the diameter of the corallites is mentioned as varying from a minimum, representing the youngest stage, to a maximum which is usually the width in the mature growth. Occasionally a mature corallite may be larger than its associates because of more available space for growth, but in general the size remains fairly uniform. The latter measurement is the only one given in the present descriptions.

Fragments and thin sections of the types of herein described species are in the collections of the United States National Museum, but the types themselves are in the custody of Dr. Tolmachoff at Pittsburgh until they can be transmitted to the cabinet of the Geological Museum of the Russian Academy of Sciences.

DESCRIPTIONS OF GENERA AND SPECIES

TETRACORALLA—FAVOSITIDAE

Genus PARAFAVOSITES Orlov, 1930

Parallelopora HOLTEDAHL, 1914; Rept. 2d Norwegian Arctic Exped., *Fram*, 1898–1902, no. 32, p. 13. (Genotype, *P. favositiformis* Holtedahl.)

Parafavosites ORLOV, 1930, U.S.S.R. Geol. Prosp. Service Bull., vol. 49, no. 3, p. 122.

Parallelopora, STRAND, 1934, Folia zool. hydrobiol., vol. 6, p. 271. (New name for *Parallelopora* Holtedahl, 1914, not Bargatzky, 1881.)

Corallum of flat to hemispherical masses composed of polygonal thin-walled corallites usually in close contact, with the mural pores and other features of *Favosites* but differing in the development at rather frequent intervals between the walls, most often at the angles, of cylindrical tubes without tabulae or septa. These circular structures vary little in diameter and arrangement in the same species. Inconspicuous septa, often reduced to minute spines, project directly into the corallite cavities, differing thus from *Astrocerium* where they are directed upward.

In thin sections the circular tube appears as a rather thick walled cylinder with the same structure as the ordinary corallites save for the absence of tabulae and septa. These tubes are not merely young corallites, for they maintain the same diameter and continue unchanged to the surface of the

[1] Tolmachoff, I. P., 1912, Geology and geography of the area of the Khatanga Expedition: Russ. Geog. Soc. Bull., vol. 48.

corallum although not always in a direct line. Nor are they mere perforations in the colony open at the exterior for the ingress of mud and debris. They, therefore, certainly had a function of their own.

Genotype.—P. ferganensis Orlov, 1930. Silurian, Ferghana District, Turkestan.

The Devonian genus *Gephuropora* Etheridge, 1920 (see figures 26, 27) is closely related to *Parafavosites* but differs in the presence of tabulae in the interior of similar special tubes. As in other favositoids the tabulae in *Parafavosites* are more closely spaced in the older thickened portion of the corallites and farther apart in the younger portion, so that mature and immature zones can be distinguished as in the Bryozoa. In the massive coralla the two zones may be repeated many times as the colony grows in size.

Noting that the generic name *Parallelopora* was preoccupied among the stromatoporoids by Bargatzky in 1881, Strand, who has inadvertently proposed homonyms in many branches of natural history because of failure to search the previous literature on the subject, replaced it with *Parallelopora*. *Parafavosites* assumes considerable importance as a genus with its interesting geographic distribution in the two species described from Turkestan by Orlov in 1930, the one from Ellesmereland, and now the five new forms from the Silurian rocks of north-central Siberia, all possessing the characteristic untabulated tubes and delicate inwardly directed spiniform septa.

PARAFAVOSITES FERGANENSIS Orlov
Figures 7, 8

Parafavosites ferganensis ORLOV, 1930, U.S.S.R. Geol. Prosp. Serv. Bull., vol. 49, no. 3, p. 122, pl. 1, fig. 12, pl. 2, figs. 1, 3 (*?P. weberi*).

Judging from the original illustrations here reproduced at a uniform magnification, this species is characterized by thin-walled corallites about 1.5 mm. wide, in close contact, with narrow, hollow untabulated cylindrical tubes 0.2 mm. in diameter developed at almost every angle and occasionally between adjacent walls. The close tabulation of the corallites with four tabulae in the length of one diameter in the mature (crowded) zone and two in the immature region, the septa reduced to minute spicules, and the mural pores also small and inconspicuous, are additional characters.

Occurrence.—Silurian; Cliffs, River Isphara, south of Matsch, Ferghana district, Turkestan.

PARAFAVOSITES WEBERI Orlov
Figures 17–19

Parafavosites weberi ORLOV, 1930, U.S.S.R. Geol. Prosp. Serv. Bull., vol. 49, no. 3, p. 124, pl. 1, figs. 3, 4, pl. 2, fig. 2.

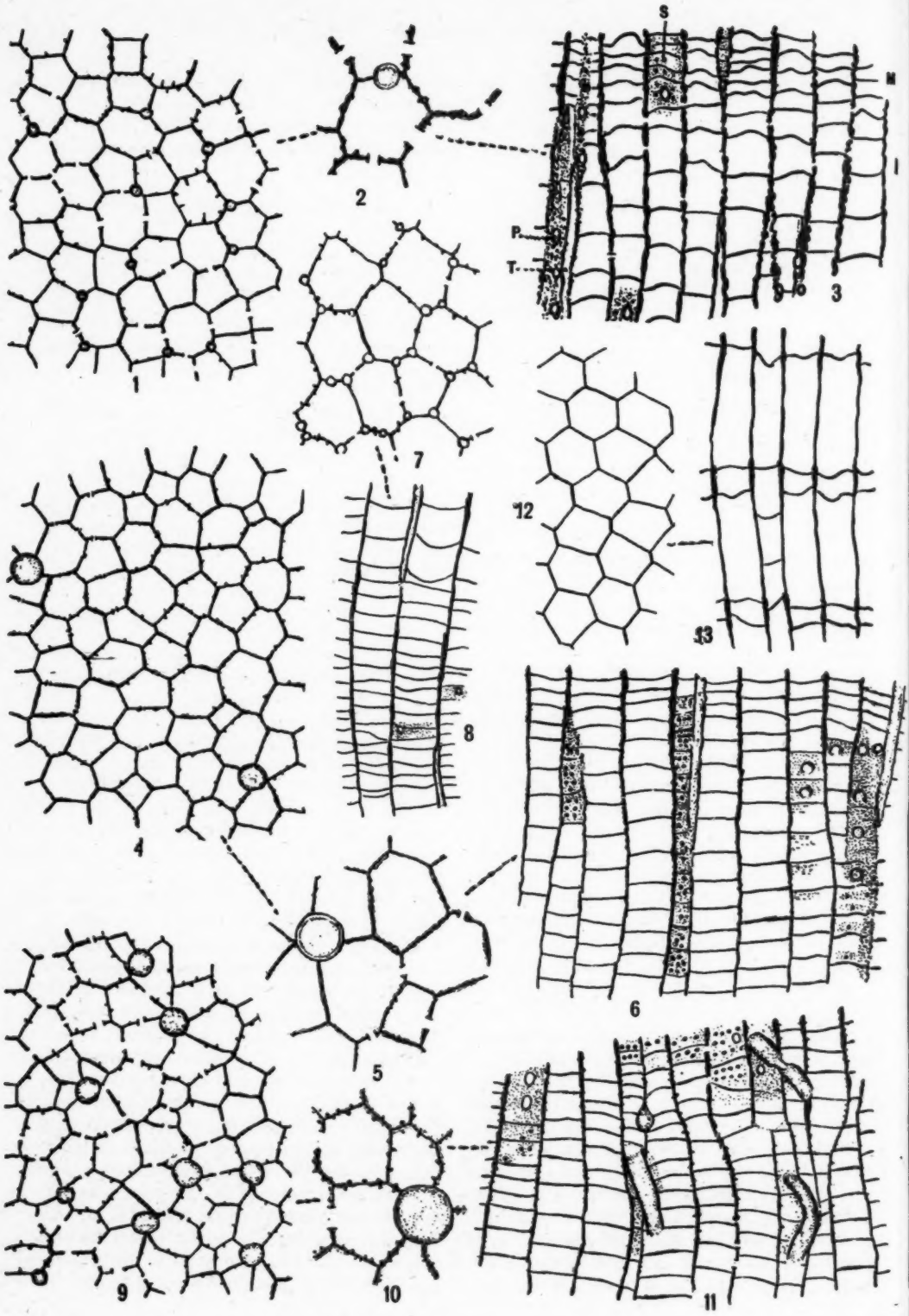
As shown by Orlov's figures, this species has corallites averaging 1.0 mm. in width, with closely spaced tabulae, 8 in a tube diameter in the mature zone, and untabulated tubes apparently of two sizes, one 0.25 mm. wide at the angles, and smaller (0.1 mm.), more numerous ones in the intervening walls. *P. weberi* is in contrast with the associated genotype, *P. ferganensis*, in which the corallites average 1.5 mm., the tubes are of a uniform diameter of 0.2 mm., and the tabulae are not so closely spaced.

Occurrence.—Silurian; Cliffs, River Isphara, south of Matsch, Ferghana district, Turkestan.

PARAFAVOSITES FAVOSITIFORMIS (Holtedahl)
Figures 1–3

Parallelopora favositiformis HOLTEDAHL, 1914, Rept. 2nd Norwegian Arctic Exped., *Fram*, 1898–1902, no. 32, p. 13, pl. 4, figs. 3–4; pl. 5, figs. 1–5.

A fragment of the holotype of this species presented by Dr. Holtedahl, has permitted the preparation of the thin sections illustrated herewith. The type colony is a flat, subhemispherical mass, 11 cm. wide by 4 cm. high, composed, as in an ordinary *Favosites*, of thin-walled polygonal corallites here averaging 1.2 mm. in width but exhibiting a circular tube of about 0.3 mm. in diameter, developed in the walls at rather regular intervals of about 2.5 mm. In the corallites proper, minute septal spines occur, sometimes four or five visible in a tube circumference, shown in the mature portion of transverse sections but more often as black dots in the walls of longitudinal ones. The tabulae are developed in two zones, an immature one where they are spaced from 1 to 1.5 corallite diameters apart, and a mature one where three to four occur in one diameter. The mural pores are oval, 0.2 mm. by



FIGS. *1–13.*—For explanation see opposite page.

0.3 mm., placed lengthwise in one or two longitudinal rows along the walls.

Occurrence.—Silurian (Series B); Valley south of Borgen, southwestern Ellesmereland, Arctic America.

PARAFAVOSITES TOLMACHOFFI
Bassler, n. sp.
Figures 4–6

Corallum subhemispherical, the type being 8 cm. wide and 2 cm. high, composed of pentagonal and hexagonal thin-walled corallites, 1.2 mm. in diameter, which display quite regularly at intervals of several diameters the openings of the cylindrical untabulated tubes characterizing the genus. These cylinders are unusually wide (0.8 mm.) averaging more than half the corallite, and are spaced at intervals of six or more corallites. In thin sections the normal corallites show a long immature zone of growth with two to three tabulae in one diameter and a short mature zone where four occur in the same distance. Circular mural pores of moderate size (0.33 mm.) in one or two rows perforate the walls. Septa spinelike, numerous, small and inconspicuous, arranged in transverse rows, best shown by their bases as black dots in the walls of longitudinal sections.

Closely allied to *P. favositiformis* in size of corallites and other features, *P. tolmachoffi* is readily recognized by its unusually large but few untabulated, widely spaced, cylindrical tubes and large rounded mural pores.

Occurrence.—Silurian; River Moyero, 1 mile below mouth of Moyerocan River and 2 miles below mouth of Jeromo River, Khatanga district, Siberia.

PARAFAVOSITES GERMANA Bassler, n. sp.
Figures 9–11

Type specimen a depressed hemispherical mass, 6.5 cm. wide by 3.0 cm. high, composed of thin-walled polygonal corallites averaging 1.4 mm. in diameter, pierced at intervals of 2 to 3 cm. by the characteristic cylindrical untabulated tubes, about 0.8 mm. in diameter. In thin sections delicate spinelike septa appear in the mature stage; while in both stages there are oval mural pores, 0.3 mm. in length, and cylindrical tubes which are quite tortuous as only portions of them appear in the plane of the section. Thin horizontal septa at distances of about two-thirds a diameter cross the immature portion of the corallites; these are more crowded in the mature portion, where two or three occur in the same distance.

Although evidently closely related to *H. tolmachoffi*, the corallites in *P. germana* are slightly larger, the septal spines are more abundant, but particularly the untabulated cylindrical tubes are more numerous, closely

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EXPLANATION OF FIGURES 1–13

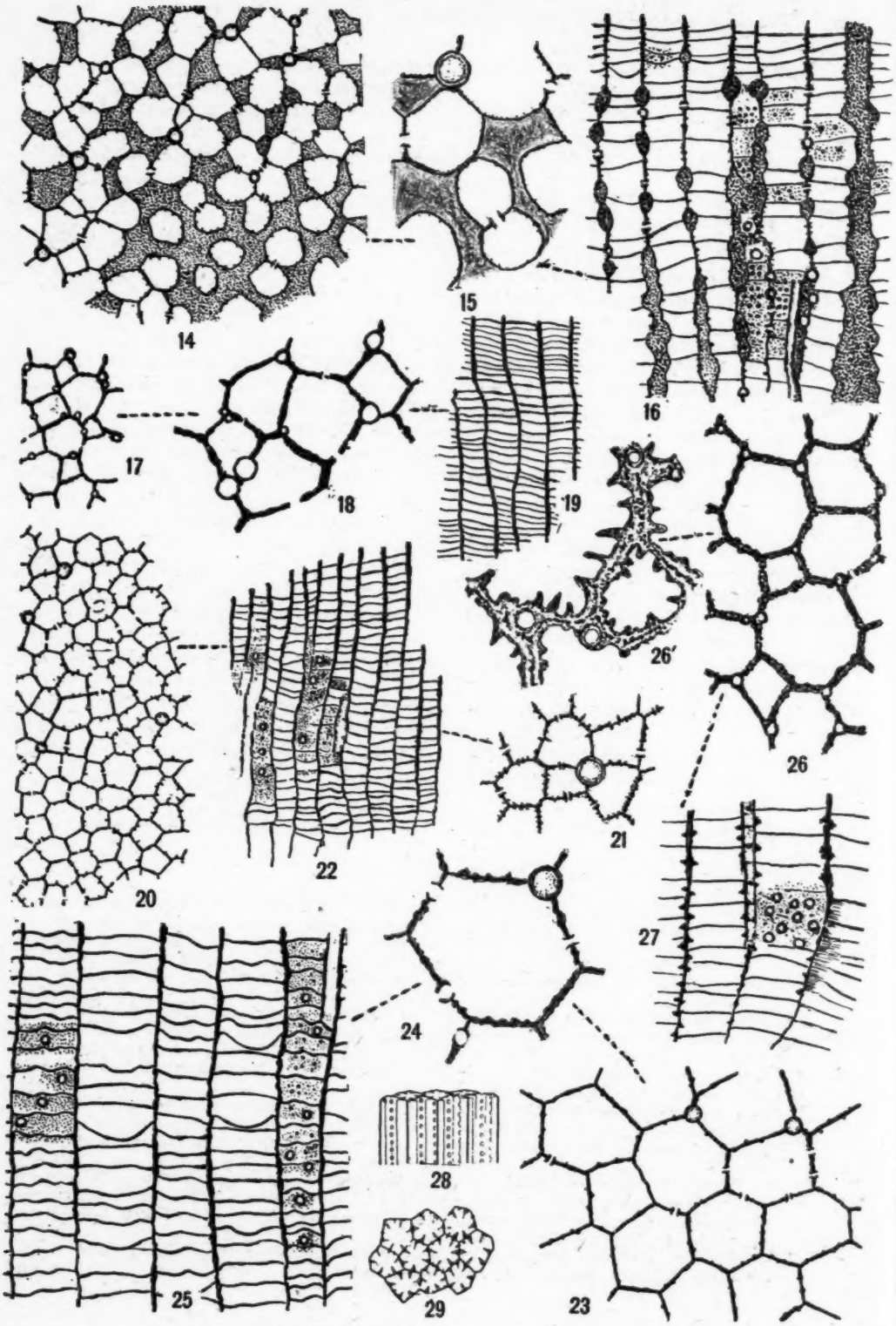
FIGS. *1–3—Parafavosites* (*Parallelopora*) *favositiformis* (Holtedahl) 1914. *1, 2*, Tangential section of the holotype, ×6 and ×12, showing thin walls, uniform size and placing of tubes, mural perforations, and occasional septa. *3*, Longitudinal section of same, exhibiting tabulation in two zones, oval mural pores, large dots representing septa, and untabulated tubes between corallites. (I, Immature region; M, mature region; P, mural pore; S, bases of septa; T, tubes). (p. 43)

4–6—Parafavosites tolmachoffi Bassler, n. sp. *4, 5*. Tangential section, ×6, and portion, ×12, exhibiting wide spacing of large cylindrical tubes. *6*, Longitudinal section, ×6; the arrangement of tabulae, portions of two cylindrical untabulated tubes, round mural pores, and bases of septa in transverse rows are seen. Silurian: River Moyero, 1 mile below mouth Moyerocan River, Khatanga area, Siberia. (p. 45)

7, 8—Parafavosites ferganensis Orlov, 1930. Orlov's illustrations reduced to ×6. The close tabulation of the corallites, small tubes of uniform size without tabulae, small mural pores, and inconspicuous septa are the diagnostic features. Silurian: Ferghana District, Turkestan. (p. 43)

9–11—Parafavosites germana Bassler, n. sp. *9, 10*, Tangential sections, ×6 and ×12 respectively, showing relationship to *P. tolmachoffi*. *11*, Vertical section, ×6, exhibiting tortuous untabulated tubes, oval mural pores, and delicate septa. Silurian: River Kotui, 1 mile from mouth Coldy River, Khatanga area, Siberia. (p. 45)

12, 13—Hattonia etheridgei Jones, 1927. Copies of the original figures, showing simplicity of structure. Silurian: Hatton's Corner, Yass, Australia. (p. 48)



FIGS. *14–29*.—For explanation see opposite page.

spaced, and the mural pores oval and smaller.

Occurrence.—Silurian; River Kotui, 1 mile from mouth of Coldy River, Khatanga area, Siberia.

PARAFAVOSITES MAGNA Bassler, n. sp.
Figures 23–25

Corallum a solid, hemispherical mass, 11 cm. wide and 5 cm. high, composed of large, polygonal, thin-walled corallites nearly 2 mm. in average diameter, and provided with cylindrical untabulated tubes of about 0.4 mm. width, placed at irregular distances from each other. In thin sections the mural pores are seen to be small (0.16 mm.), circular, and in three longitudinal rows; the tabulae are crowded in the mature zone with five to six in a corallite diameter and about half that many in the immature region. The septa appear as minute spines little visible in tangential sections but well shown in the longitudinal one where their bases are cut.

The large size of the corallites, their thin walls, the small irregularly and widely scattered cylindrical tubes of uniform size, and the three rows of small, round mural pores, are characters by which this species can be readily recognized.

Occurrence.—Silurian; River Kotui, 1 mile from mouth of Coldy River, Khatanga area, Siberia.

PARAFAVOSITES SIMILIS Bassler, n. sp.
Figures 20–22

The structure in this species is so similar to *Astrocerium* that were it not for the presence of the cylindrical untabulated tubes among the ordinary corallites and the straight spiniform septa, it would be classified in that genus. The corallites, too, in their small size, averaging 0.70 mm. in width, and the presence of mural pores also remind of that genus. The cylindrical tubes (0.25 mm. wide), however, and the septa are exactly the same as in the other forms of *Parafavosites*. This species has the smallest corallites so far known in the genus.

Occurrence.—Silurian; River Moyero, 1 mile below mouth of Moyerocan River and 2 miles below mouth of Jeromo River, Khatanga area, Siberia.

PARAFAVOSITES SEPARATA Bassler, n. sp.
Figures 14–16

The several colonies of this species, each a hemispherical mass about 6 cm. wide,

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EXPLANATION OF FIGURES 14–29

FIGS. *14–16—Parafavosites separata* Bassler, n. sp. Tangential section, ×6, with a portion, ×12, and vertical section, ×6, showing some corallites in contact and others separated from each other. Round mural pores, delicate spiniform septa and cylindrical untabulated tubes are present as in the typical species of the genus. Silurian: River Kotui, 1 mile from mouth of Coldy River, Khatanga area, Siberia. (p. 47)

17–19—Parafavosites weberi Orlov, 1930. *17, 18,* Tangential section, ×6 and ×12, showing large and small size of tubes. *19,* Vertical section, ×6, with very close tabulation called *P. ferganensis* by Orlov but probably in error for *P. weberi*. Silurian: Ferghana District, Turkestan (copied after Orlov, 1930). (p. 43)

20–22—Parafavosites similis Bassler, n. sp. *20, 21,* Tangential section, ×6, and several corallites, ×12, with characters similar to the genus *Astrocerium* save the presence of untabulated tubes. *22,* Vertical section, ×6, exhibiting small size and close tabulation of corallites as well as the small round mural pores, minute septa, and few untabulated tubes. Silurian: River Moyero, 1 mile below mouth of Moyerocan River, Khatanga area, Siberia. (p. 47)

23–25—Parafavosites magna Bassler, n. sp. *23, 24,* The large thin-walled corallites with delicate spiniform septa, circular mural pores, and untabulated tubes, ×6 and ×12. *25,* Vertical section, ×6, with short immature zones and mural pores arranged in three rows. Silurian: River Kotui, 1 mile from mouth of Coldy River, Khatanga area, Siberia. (p. 47)

26, 26′ 27—Gephuropora duni (Etheridge), 1920. *26, 26′,* Corallites in mature zone of tangential section, ×6, and a portion cutting an older condition of the colony, ×12. The tubes and short blunt septa are conspicuous in the latter. *27,* Vertical section, ×6, showing several rows of circular mural pores to a wall, and the tabulated tube and stout spiniform septa. Devonian: Cavan, Murrumbidgee River, New South Wales. (p. 48)

28, 29—Boreaster lowi Lambe, 1906. Vertical and tangential sections reduced to ×6 from the original figures and showing the combination of mural pores of *Favosites* with lamellar septa as in *Favistella*. Silurian: Beechey Island, Lancaster Sound, Arctic America (after Lambe 1906). (p. 49)

present the usual characters of thin-walled, angular corallites pierced at irregular, fairly close intervals by the characteristic cylindrical, untabulated tubes. They differ from other forms of the genus in that the corallites are often separated by expanding and contracting hollow spaces, which are external in origin as shown by their filling of clay and other matter. Longitudinal sections exhibit some of the corallites separated for only short distances; in others the empty spaces between them enlarge and then pinch out, while in still others according to the degree of contact of the corallite walls, they are completely isolated by continuous wide spaces. Other genera of Paleozoic corals exhibit such a tendency for the separation of the corallites in a few of their species, so that it is not an unusual feature here. The corallites themselves are 1.2 mm. in diameter, exhibit minute spinelike septa in thin sections, and tabulae one-half to one corallite diameter apart in the immature region and more closely arranged (four in one diameter) in the mature zone. Longitudinal sections cutting the walls along the flat surface show circular mural pores 0.20 mm. wide, the bases of the spinelike septa here arranged in parallel transverse rows, and the cylindrical tubes with a diameter of 0.40 mm.

Occurrence.—Silurian; River Kotui, 1 mile from mouth of Coldy River, Khatanga area, Siberia.

Genus SAPPORIPORA Ozaki, 1934

Sapporipora OZAKI, 1934, Shanghai Science Inst. Jour. sec. 2, vol. 1, p. 74.

Corallum massive, corallites small, rather uniformly polygonal, prismatic and united by their walls, which are perforated by very large pores arranged in a single row. Size of pores, which are almost always situated in the middle of walls, attains to one-third or more of width of wall. Walls of corallites rather thick. Tabulae seem numerous, complete, horizontal, situated at regular intervals.

Increase of corallites almost always at junction of four walls; junction expands to hollow tube, which increases in diameter upwards until it becomes a new corallite perforated by large pores in a single row. (Ozaki 1934).

Genotype and only species: *S. favositoides* Ozaki (1934, p. 75, pl. 15, figs. 5–7). Gotlandian of northwest Korea.

The photographs of the type and thin sections show no characters other than the small size of the corallites (nine in 5 mm.) and the occurrence of tabulae (nine or more in 3 mm.). The description indicates the absence of septa and the presence of nine mural pores in 3 mm. in a single row. Thus. the essential generic feature seems to be the hollow tube at the junction of four walls which expands into a typical corallite. This sounds unnatural, but it may be possible that the structure is the same as in *Parafavosites* Orlov, 1930.

Genus HATTONIA Jones, 1927

Hattonia O. A. JONES, 1927, Geol. Mag., vol. 64, p. 438.

Corallum compound, massive. Corallites prismatic, polygonal, firmly amalgamated. Septa and mural pores absent. One to three or more tabulae occurring in groups which are regularly spaced and on the same level in contiguous corallites. Reproduction by intramural gemmation. (Jones 1927.)

Genotype: *Hattonia etheridgei* Jones (1927, p. 438, pl. 12, figs. 12, 30), Silurian (Barrandella shales): Hatton's Corner, Yass, Australia.

A copy (figs. 12, 13) of the original figures of the genotype and only known species, at a magnification of ×6, for ready comparison, is introduced here to call attention to this interesting coral. Should mural pores and septa be really lacking, it might be classed as a *Lichenaria*, but it is suspected that a tangential section directly through the slightly thickened mature region marked by the zone of a few tabulae will show favositoid characters.

Genus GEPHUROPORA Etheridge, 1920

Columnopora LECOMPTE, 1939 (not Nicholson, 1872), Mus. Royal histoire Nat. Belgique Mém. 90, p. 95.

Columnopora (*Gephuropora*) ETHERIDGE, 1920, New South Wales Geol. Survey Rec., vol. 9, no. 2, p. 60.

Columnopora (*Gephuropora*), O. A. JONES, 1941, Royal Soc. Queensland Proc., vol. 53, no. 3, p. 51.

Tabulate corals in which small longitudinal tabulate tubules occur in some of the corners of the corallites and more rarely in the common wall of two corallites. The septa are spinose but prob-

ably have short lamellar bases. Mural pores are present. (Jones 1941.)

Genotype: *Favosites* (*?Columnopora*) *duni* Etheridge (1920, p. 6, pls. 14, 15, 1920). Devonian; Cavan, Murrumbidgee River, New South Wales.

Thin sections of a topotype of the genotype (figs. 26, 27) indicate that *Gephuropora* differs from *Parafavosites* only in the tabulation of the tubes scattered among the corallites and in the stronger development of the spiniform septa.

Lecompte (1939) has described three species of *Gephuropora* from the Devonian of the Dinant basin as *Columnopora gilsoni* Salée, *C. maillieuxi* Salée and *C. spinosa* Lecompte. These show clearly the tabulated intermural tubes characteristic of *Gephuropora* and are quite different generically from true *Columnopora*.

Genus BOREASTER Lambe, 1906

Boreaster LAMBE, in LOW, 1906, Rept. Dominion Gov. Exped. to Hudson Bay and Arctic Islands, D. G. S., *Neptune*, 1903–4, Appendix 4, p. 4.

Corallum composite, massive (or thickly incrusting) made up of intimately connected polygonal corallites communicating with each other by means of mural pores. Septa in the form of longitudinal lamellae, 12 in number. Tabulae simple. (Lambe, 1906.)

Genotype (figs. 28, 29) and only known species: *B. lowi* Lambe (1906, p. 4, fig.). Silurian: Beechey Island, Lancaster Sound, Arctic America.

The type species of thin-walled corallites, averaging about 0.75 mm. in diameter, has relatively large oval mural pores in a single row between each pair of six primary lamellar septa. The latter are stout and large, while a secondary set of six is rudimentary. Tabulae not numerous and in the form of simple, flat, transverse diaphragms.

As no specimen of this species is available for study at the present time, the above characters have been selected from Lambe's original description and remarks. The small corallites, the lamellar septa in two series, and the arrangement of the mural pores in parallel lines between the primary septa, seem to indicate a distinct generic type, possibly a simple form of the Favositidae, retaining the characteristic septa of the rugose corals. Possibly thin sections were not employed in the study of this species, so there may be a chance for error in the interpretation of its characters.

Genus PLASMADICTYON Wilson, 1926

Plasmadictyon WILSON, 1926, Canada Geol. Survey Bull. 44, p. 19.

The type and only known species of this genus was based upon two silicified thin expansions, 38 mm. wide and less than 5 mm. thick, composed of small, variously shaped corallites from $\frac{1}{2}$ mm. to $\frac{3}{4}$ mm. in diameter some surrounded by minute tubules, which on a longitudinal section of a well-preserved part show three large complete pores arranged in a vertical row. This last feature, suggesting *Favosites*, occasions mention of the genus in this paper. The types are not available.

Genotype: *P. irregulare* Wilson (1926, p. 19, pl. 1, figs 11, 12). Richmond (Beaverfoot formation): Stoddart Creek Section, Windermere Area, B. C.

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CATALOGUE AND REVISION OF THE GASTROPOD SUBFAMILY TYPHINAE

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ABSTRACT—The Typhinae, a subfamily of the Muricidae, number about 85 species, ranging in time from lower Eocene (Ypresian) to Recent. Although widely distributed geographically, they are most abundant in three areas, both in the fossil and the Recent record; namely, in the Australasian, the European, and the Middle American regions. In spite of the relatively small number of species it seems desirable to recognize 13 subgeneric and generic units, one of which, *Indotyphis*, is here proposed as a new subgenus of *Laevityphis*. Allocation of species in the revised classification is facilitated by an illustrated key. The Typhinae should prove useful as index fossils, first, because of the progressive change in certain morphologic characters such as in the placement of the tube that is the distinctive feature of this group, and second, because each fossil species seems to be of short duration in time.

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INTRODUCTION

It is 65 years since even a partial summary of species for this group of the Muricidae has been attempted. As the fossil forms are potentially useful in stratigraphic correlation, a new catalogue of species and a review of the superspecific units are here offered.

In the present list there are 105 names of species. Elimination of synonyms and rejection of forms not properly assignable to the Typhinae reduce this number to around 85, of which 28 are Recent. These eighty-odd species, as will be shown, can be distributed on the basis of morphologic characteristics

into several genera and subgenera. They have usually been classed under the one genus *Typhis*, although Jousseaume, in 1880, proposed to recognize 12 full genera in the Typhinae, with no smaller subdivisions. Up to the present, 17 superspecific names have been introduced, of which 12 seem to be justifiable, 4 as genera, 8 as subgenera. An additional subgeneric unit is proposed in this paper. Several new species that have come to light will be described later.

MORPHOLOGY

Most of the Typhinae are small shells, ranging from a minimum height, in the adult, of about 6 mm. to a maximum of 48 mm., the average height being around 15 to 20 mm. The distinguishing feature which sets the group apart from all other Muricidae is the presence of tubes alternating with the varices. These tubes are cylindrical, with an almost invisible suture along the face nearest the aperture. The last tube in each whorl opens to the interior of the shell. While open, or, in other words, while occupied by an extension of the mantle margin, the tube is long, often being nearly equal in length to the diameter of the shell proper. As soon as a new tube is formed, the inner opening of the abandoned tube is sealed over with shelly material, and the tube no longer in contact with living mantle tissue gradually disintegrates or breaks away until only a short stub is left. Dall (1889, pp. 214–216) has suggested that the open tube serves as a channel for the extrusion of effete matter from the intestine.

The protoconch or embryonic shell varies somewhat in different species. A generalized description is: Nuclear whorls two in number, rounded, smooth or slightly papillose; adult sculpture developed either (a) in first postnuclear whorl or (b) gradually through two to three postnuclear whorls, the first such whorl with a rounded shoulder, the next with spines of increasing length, the third with the first tube. In either alternative, a spine always precedes the first tube, usually about one-half turn in advance.

Concerning the soft parts Baker (1895, p. 181) says:

> Animal resembling *Murex*. . . . Foot long and narrow; tentacles thick and broad; eyes situated at their base. Operculum ovate, with sub-apical nucleus, like that of *Murex*.

The operculum and animal are figured by H. and A. Adams (1853, p. 76), and a figure of the radula of the subgenus *Typhis* (*Haustellotyphis*) is given by Thiele (1929, p. 293).

Morphological characters that seem to be of especial significance in subdividing the Typhinae are: number of tubes per whorl (varying from three to five or more); placement of tubes with respect to the varices (whether just behind a varix, just in front of it, or midway between two varices); and the direction which the tubes point, whether forward (toward the aperture), outward, or backward (away from the aperture), Some authors, relying principally upon sculpture and outline, have concluded that the group cannot be subdivided successfully because of the numerous intergrading forms. As regards the characters discussed here, no truly gradational species were observed among the material studied.

ECOLOGY

The Typhinae are, in general, animals of the neritic zone, which accounts partly for their relative scarcity in museum collections and in geological formations. In the present survey of the literature there were noticed only one mention of specimens found among beach sand and one of specimens collected at extreme low tide. All other locality records for living material were from dredgings. These range from 6 to 400 fathoms, with a median of 25 fathoms for 34 records. Only a few bottom temperatures at these depths have been reported; one record is 65°F. In spite of the depths at which they occur, the Typhinae must prefer a relatively warm environment, because they are restricted to seas in equatorial latitudes.

According to the Zoological Record for 1869, Caramagna (1869, pp. 168–170) reports that *Typhis sowerbyii* has been found gregarious on seaweed in the Gulf of Spezia; that it changes locality with the seasons and retires to deeper water in the cold season.

DISPERSAL

In the Recent fauna, 13 of the 28 named

species occur in two marine provinces, the Australian (7 species) and the Panamic (6 species). Other provinces are represented by not more than three species each. In the Tertiary the Australian region seems to be an important area of dispersal, as are also the basins of deposition in Europe and in the Caribbean. Distribution in time and space will be discussed at more length below.

KEY TO SUBDIVISIONS

The terminology used in distinguishing the various superspecific groups of Typhinae is illustrated in figure 19. Figures 1 to 18 are line drawings traced, by use of the camera lucida, from the original figures of all genotypic species. No attempt at computing magnifications of the figures is made because early authors seldom stated the dimensions of their specimens. All drawings have, instead, been brought to a standard size to facilitate comparisons of structure and relative proportions. A standard scheme of shading has been adopted.

A. Tubes per whorl three.....(B)
Tubes per whorl more than three.....(D)
B (from A). Tubes separate from but just behind varices (synonym, *Trigonotyphis*, fig. 2)..... *Pterotyphis* (fig. 1).
Tubes coalesced with varices.....(C)
C (from B). Tube openings elevated, at tips of spines.....*Tripterotyphis* (fig. 3).
Tube openings not elevated on spines or varices.....*Semityphis* (fig. 4).
D (from A). Tubes per whorl four.....(E)
Tubes per whorl more than four..... *Lyrotyphis* (fig. 5).
E (from D). Tubes twisted forward and soldered to the back of the next varix..... *Indotyphis* (fig. 6).
Tubes twisted backward, upward, or projected at right angles.....(F)
F (from E). Tubes about midway between varices .....(G)
Tubes back of or forward of midpoint between varices.....(I)
G (from F). Canal slender and long (about one-half the length of the entire shell)..... *Haustellotyphis* (fig. 7).
Canal short or moderate in length (less than half the length of the shell.....(H)
H (from G). Varices deeply notched, forming a vertical row of spines (synonym, *Hirtotyphis*, fig. 9).....*Typhis, s. s.* (fig. 8).
Varices smoothed, rounded, or only slightly wavy.....*Typhina* (fig. 10).
I (from F). Tubes back of midpoint between varices.....(K)
Tubes forward of midpoint between varices (*i.e.*, near next varix).....(J)
J (from I). Tubes soldered to varices; varices often obsolescent (synonyms, *Trubatsa*, fig. 12, and *Choreotyphis*, fig. 13)..... *Siphonochelus* (fig. 11).
Tubes not soldered to varices; varices often spiny at apex.....*Laevityphis* (fig. 14).
K (from I). Varix at outer lip sharply narrowed above aperture.....*Typhinellus* (fig. 15).
Varix at outer lip as wide throughout as diameter of aperture.....(L)
L (from K). Tubes free, not reinforced by a lamina.....*Talityphis* (fig. 16).
Tubes reinforced on posterior side by a lamina which connects each whorl to previous whorl (synonym, *Typhisala*, fig. 18)..... *Typhisopsis* (fig. 17).

REVISED CLASSIFICATION

Although the Typhinae are distributed throughout the world in tropical and subtropical seas and have been in existence since at least the lower Eocene, specimens are not abundant at any time or place. Even the large museum collections are apt to have fewer than a dozen species, each represented by only a few specimens. Consequently the present revision must depend heavily upon published illustrations. In order that the interpretation of characters might be as accurate as possible under the circumstances, the original figures of all genotypes have been studied with unusual care. Fortunately, specimens of more than half of the genotypes have been made available to me by gift or loan, and representative species of several others are in the Stanford collection. For the benefit of students wishing to know where to consult specimens, a summary of material seen is given in the species catalog below.

The principal author of names proposed for subdivision of the Typhinae is Jousseaume, whose many innovations, supported by brief diagnoses, have been regarded with disfavor by more than one reviewer. However, faulty as his work was, Jousseaume did sense some important morphological distinctions—or so it seems in the light of present concepts of classification. Progress in the description of fossil forms has added reinforcement to a nomenclatural framework which, when based upon a few living species, seemed flimsy indeed.

Since 1900 two classifications of the 17 named superspecific units have been published. Cossmann (1903-b) recognized four

genera: *Typhis* (subdivided into two subgenera and three sections), *Cyphonochilus*, *Lyrotyphis*, and *Pterotyphis*. Thiele (1929) reduced all these to one genus, *Typhis*, subdivided into five sections. He perpetuated one of Cossmann's misinterpretations of morphology and some errors of nomenclature.

Class GASTROPODA
Subclass PROSOBRANCHIATA
Order STENOGLOSSA
Superfamily MURICACEA
Family MURICIDAE Fleming, 1828
Subfamily TYPHINAE Cossmann, 1903

TYPHINAE Cossmann, 1903-b, p. 7.
TIPHINAE Cossmann. Sacco, 1904, p. 17. [Misspelling.]
THYPHINAE Sacco, 1904, p. 203. [Emendation of Tiphinae.]
TYPHIDAE Sacco, 1904, p. 201.

Shells of small to medium size (minimum height of adult about 6 mm., maximum height about 50 mm.); turreted, with hollow tubes at shoulders of whorls, alternating with or coalesced to varices; tubes and varices 3 to 6 per whorl; aperture small, ovate; anterior canal usually closed, tubular, and twisted obliquely to the right or backward away from aperture, remnants of former anterior canals, abandoned as growth proceeds, persisting in a wide spiral simulating a siphonal fasciole above pillar; nuclear whorls two, smooth or papillose, glassy, postnuclear whorls one to three prior to formation of first varix, first tube following within next one-half whorl.

Genus TYPHIS Montfort, 1810

Typhis DENYS DE MONTFORT, 1810, pp. 614–615.
Tiphys AGASSIZ, 1846. Nomen. Zool. Index Univ. [Unjustifiable emendation.]
Tiphis D'ORBIGNY, 1850, p. 364. [Unjustifiable emendation.]
Hirtotyphis "Bayle MS" JOUSSEAUME, 1880,[1] p. 336. Type, by original designation, *Typhis horridus* (Brocchi) = *Murex horridus* Brocchi, 1814.
Hirtotyphis, JOUSSEAUME, 1882, p. 338. Placed in synonymy of *Typhis* by Cossmann, 1903-b.

Type (by original designation): *Purpura tubifer* Bruguière, 1792.

Diagnosis: Each whorl with four varices and four tubes; tubes either intermediate between varices or nearer to preceding varix.

Discussion: Wrigley (1930, p. 112) considers that *Murex pungens* Solander, 1766, is a prior name for *Typhis tubifer*. Although Montfort mentioned *M. pungens* in the synonymy of *P. tubifer*, he definitely cited *P. tubifer* as type of the new genus *Typhis*. I regard the two names as referring to specifically distinct entities. The original figure of *M. pungens* shows a shell having only about half as many spines per varix as the shell in the original figure of *P. tubifer*. Both forms are assignable to *Typhis, s. s.*

Subgenus TYPHIS, *sensu stricto*

Diagnosis: Varices dissected into spines by spiral sculpture; tubes midway between varices.

Species: [for references, see species catalogue, below].

Typhis (*Typhis*) *horridus*—Pliocene, Italy
Typhis (*Typhis*) *intermedius*—Miocene, Italy
Typhis (*Typhis*) *peyreirensis*—Oligocene, France
Typhis (*Typhis*) *pungens*—Eocene, England
Typhis (*Typhis*) *rutoti*—Eocene, France
Typhis (*Typhis*) *tubifer*—Eocene, France

Subgenus TYPHINA Jousseaume, 1880

Typhina JOUSSEAUME, 1880, p. 335; 1882, p. 337.

Type (by original designation): *Typhis belcheri* Broderip, 1833.

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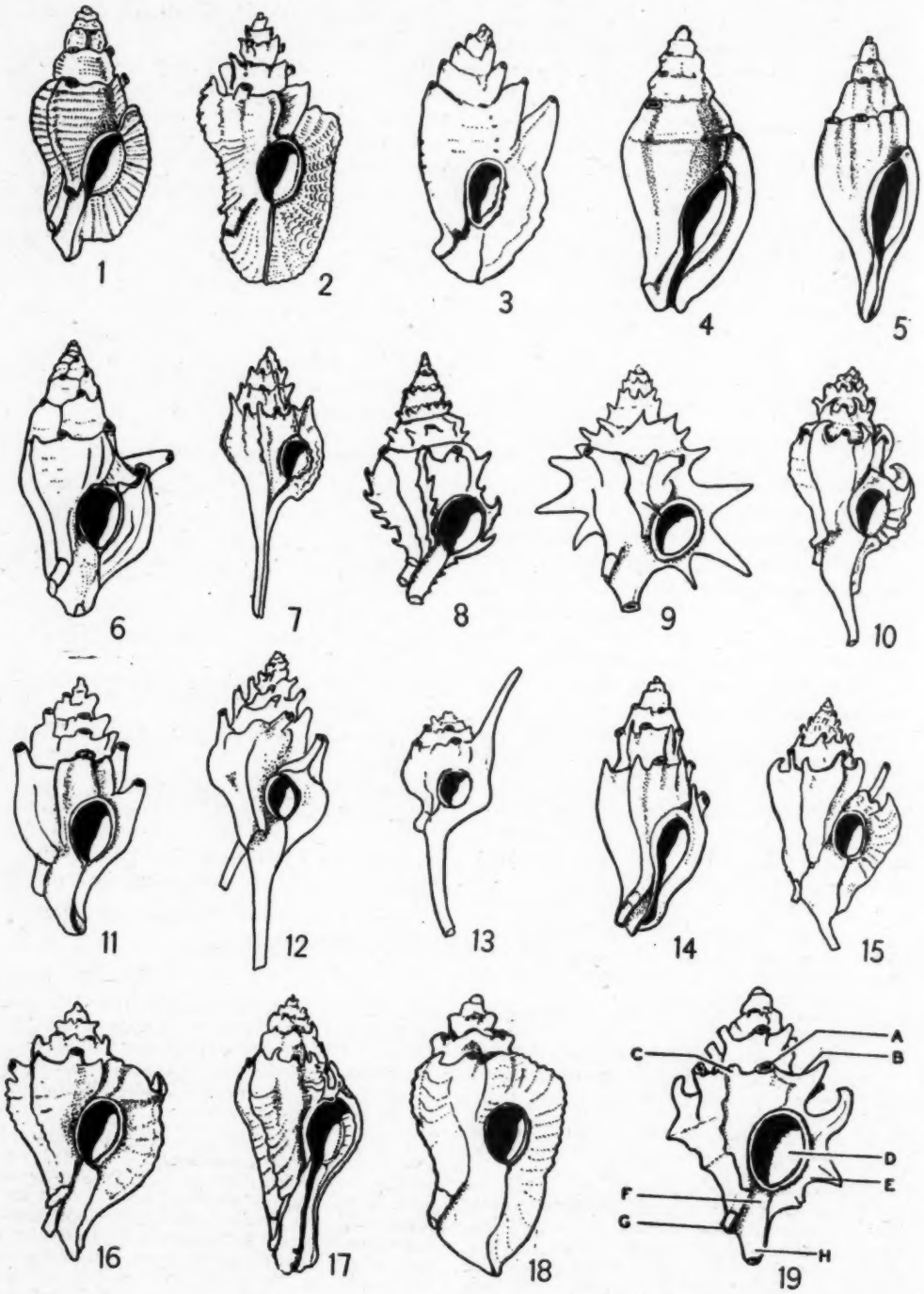
[1] Jousseaume is the author of two papers on the Muricidae. His chief work, which was scheduled to appear in 1879, was delayed in printing. To give availability to the new names proposed therein, he published a brief summary in "Le Naturaliste" for December 15, 1880; corrections of some typographical errors and mention of the existence of others were made in the February 15, 1881, number of the same journal. It is clear that the principal work had not yet appeared in December, 1880, for Jousseaume states (p. 336):

> "Nous publierons dans les premiers fascicules de la *Revue et Magasin de Zoologie* la diagnose de chacun de ces genres . . . "

The "Revue" for 1879 was not published until 1881, according to some authors, or 1882, according to Iredale (1924, p. 272). Whatever the date of publication, it is evidently post-1880. Most of Jousseaume's names, therefore, must date from 1880, not 1879, as cited by Dall (1923) and others. Differences between Jousseaume's two papers in the matter of spelling certain names have added complexities which will be discussed below.



FIGS. *1–19*.—For explanation see opposite page.

Diagnosis: Varices entire or slightly crenulated; tubes midway between varices.

Discussion: According to Dall (1923, p. 77), *Typhina* Jousseaume is a homonym of *Typhina* Burmeister, 1834. In his work entitled "Beiträge zur Naturgeschichte der Rankenfüsser" Burmeister on page 56 does use the name, but for a family of the Amphipoda; it is therefore not available under the International Rules of Zoological Nomenclature and does not preoccupy the generic name *Typhina* Jousseaume.

Species:

Typhis (*Typhina*) *acuticosta*—Miocene, Maryland

Typhis (*Typhina*) *belcheri*—Recent, West Africa

Typhis (*Typhina*) *bivaricatus*—Recent, South Australia

Typhis (*Typhina*) *dentatus*—Eocene, Mississippi

Typhis (*Typhina*) *gabbi*—Miocene, Panama

Typhis (*Typhina*) *harrisi*—Miocene, Florida

Typhis (*Typhina*) *quadratus*—Recent, Ecuador

Typhis (*Typhina*) *tetragoniatus*—Pliocene, India

Typhis (*Typhina*) *waltonensis*—Miocene, Florida

Subgenus HAUSTELLOTYPHIS Jousseaume, 1880

Haustellotyphis JOUSSEAUME, 1880, p. 335; 1882, p. 338.

Type (by original designation): *Typhis cumingi* Broderip = *Typhis cumingii* Broderip, 1833.

Diagnosis: Varices surmounted by tapering, uncurved spines; canal longer than spire, slender, not oblique, with no persistent abandoned canals above pillar; tubes midway between varices.

Species:

Typhis (*Haustellotyphis*) *cumingii*—Recent, Panamic province

Subgenus TYPHINELLUS Jousseaume, 1880

Typhinellus JOUSSEAUME, 1880, p. 335; 1882, p. 337.

Type (by original designation): *Typhis*

EXPLANATION OF FIGURES 1–19

FIG. *1*—*Pterotyphis* (*Pterotyphis*) *pinnatus* (Broderip). After Sowerby, 1941. (p. 66)

2—*P.* (*P.*) *fimbriatus* (A. Adams). Genotype of *Trigonotyphis* Jousseaume. After Sowerby, 1874. (p. 64)

3—*P.* (*Tripterotyphis*) *lowei* (Pilsbry). After Pilsbry and Lowe, 1932. (p. 65)

4—*P.* (*Semityphis*) *incisus* (Martin). After Martin, 1931. (p. 65)

5—*Siphonochelus* (*Lyrotyphis*) *cuniculosus* (Nyst). After Nyst, 1836. (p. 64)

6—*Laevityphis* (*Indotyphis*) *bantamensis* (Oostingh). After Oostingh, 1933. (p. 63)

7—*Typhis* (*Haustellotyphis*) *cumingii* Broderip. After Sowerby, 1841. (p. 64)

8—*T.* (*Typhis*) *tubifer* (Bruguière). After Bruguière, 1792. (p. 67)

9—*T.* (*T.*) *horridus* (Brocchi). Genotype of *Hirtotyphis* Jousseaume. After Brocchi, 1814. (p. 65)

10—*T.* (*Typhina*) *belcheri* Sowerby. After Sowerby, 1841. (p. 63)

11—*Siphonochelus* (*Siphonochelus*) *arcuatus* (Hinds). After Sowerby, 1866. (p. 63)

12—*S.* (*S.*) *longicornis* (Dall). Genotype of *Trubatsa* Dall. After Dall, 1888. (p. 65)

13—*S.* (*S.*) *pavlova* (Iredale). Genotype of *Choreotyphis* Iredale. After Iredale, 1936. (p. 66)

14—*Laevityphis* (*Laevityphis*) *coronarius* (Deshayes). After Deshayes, 1865. (p. 64)

15—*Typhis* (*Typhinellus*) *sowerbyii* Broderip. After Sowerby, 1841. (p. 67)

16—*T.* (*Talityphis*) *expansus* Sowerby. After Sowerby, 1874. (p. 64)

17—*T.* (*Typhisopsis*) "*coronatus*" Broderip (= *T. grandis* A. Adams). After Sowerby, 1841. (p. 64)

18—*T.* (*Typhisopsis*) *grandis* A. Adams. Genotype of *Typhisala* Jousseaume. After Adams, 1855. (p. 65)

19—*T.* (*Typhis*) *pungens* (Solander). After Wrigley, 1930. Terms used in descriptions of Typhinae: A, tube; B, the preceding varix; C, the succeeding varix (note that the distance B-A-C comprises one period of growth); D, aperture; E, outer lip; F, pillar (the area between the suture of the anterior canal and the remnants of former canals, representing the axis of rotation of the shell); G, remnants of earlier anterior canals; H, anterior canal. (p. 66)

sowerbiyi Broderip = *Typhis sowerbyii* Broderip, 1833.

Diagnosis: Tubes nearer to preceding than to succeeding varices, usually backward-pointing; varix at outer lip relatively narrow, especially above aperture; spiral sculpture usually present, occasionally dissecting varices as in *Typhis, s. s.*

Discussion: In spite of the fact that the name *Typhis sowerbyii* Broderip, 1833, is prior to the name *Typhis tetrapterus* (Bronn), 1838, the species is commonly cited in the literature under the latter name. According to Kobelt (1877, p. 287), *Murex labiatus* Cristofori and Jan, 1832, is a synonym of *Typhis tetrapterus*. If this is true, the name *Typhis sowerbyii* must be replaced by *T. labiatus* (Cristofori and Jan), which has a year's priority. However, as Bellardi (1873, p. 42) had earlier placed *Murex labiatus* in the synonymy of *M. fistulosus* Brocchi, 1814, it is possible that the species of Cristofori and Jan may be regarded as a *species dubium*. A copy of their work has not been available to me.

Species:

(?) *Typhis* (*Typhinellus*) *acanthopterus*—Miocene, Australia
Typhis (*Typhinellus*) *cleryi*—Recent, Brazil
Typhis (*Typhinellus*) *floridanus*—Pliocene, Florida
Typhis (*Typhinellus*) *francescae*—Lower Oligocene, Australia
Typhis (*Typhinellus*) *hebetatus*—Miocene, New Zealand
Typhis (*Typhinellus*) *interpres*—Recent, Australia
Typhis (*Typhinellus*) *laciniatus*—Miocene, Australia
Typhis (*Typhinellus*) *macropterus*—Miocene, Java
Typhis (*Typhinellus*) *m'coyi*—Miocene, Tasmania
Typhis (*Typhinellus*) *montfortii*—Recent, Japan
Typhis (*Typhinellus*) *nitens*—Recent, Straits of Macassar
Typhis (*Typhinellus*) *pauperis*—Recent, New Zealand
Typhis (*Typhinellus*) *philippensis*—Recent, Australia
Typhis (*Typhinellus*) *protetrapterus*—Oligocene, Italy
Typhis (*Typhinellus*) *siphon*—Miocene, Jamaica
Typhis (*Typhinellus*) *siphoniferus*—Miocene, Florida
Typhis (*Typhinellus*) *sowerbyii*—Recent, Mediterranean
Typhis (*Typhinellus*) *yatesii*—Recent, Australia

Subgenus TALITYPHIS Jousseaume, 1882

Talityphis JOUSSEAUME, 1882, p. 338.

Type (by original designation): *Typhis expansus* Sowerby, 1874.

Diagnosis: Varix at outer lip greatly expanded; spiral sculpture weak; tubes nearer to preceding varix, backward-pointing.

Discussion: Cossmann misinterpreted *T. expansus* as a trivaricate form identical with or similar to the genotype of *Pterotyphis*, an error which Thiele corrected. The genotype, *T. expansus*, was described without locality. Specimens collected on the beach of Santo Domingo by A. A. Olsson compare so closely with the type figure that it seems probable that the original specimen came from the Caribbean.

Species:

Typhis (*Talityphis*) *alatus*—Miocene, Santo Domingo
Typhis (*Talityphis*) *expansus*—Recent (probably Santo Domingo)
Typhis (*Talityphis*) *lampada*—Miocene, California
Typhis (*Talityphis*) *latipennis*—Recent, Gulf of California
Typhis (*Talityphis*) *obesus*—Miocene, Santo Domingo
Typhis (*Talityphis*) *olssoni*—Pliocene, Costa Rica
Typhis (*Talityphis*) *pterinus*—Miocene, Florida

Subgenus TYPHISOPSIS Jousseaume, 1880

Typhisopsis JOUSSEAUME, 1880, p. 335; 1882, p. 337.
Typhisala JOUSSEAUME, 1882, p. 338; type (by original designation), *Typhis grandis* A. Adams.

Type (by original designation): *Typhis coronatus* Broderip, 1833 (a secondary homonym) = *Typhis grandis* A. Adams, 1855.

Diagnosis: Tubes nearer to preceding varices (in fact, appressed to them), but-

tressed by a laminar remnant of former outer lip, which joins each whorl to preceding whorl; varices rounded; spiral sculpture of raised threads in adult, lacking in young specimens.

Discussion: *Typhis coronatus* Broderip, 1833, was transferred to *Murex* by Reeve in 1842; hence, the name becomes a secondary or junior homonym of *Murex coronatus* J. Sowerby, 1819.[2] An available synonym is *Typhis grandis* Adams, the genotype of *Typhisala*. *Typhisala* thus falls as a typonym of *Typhisopsis*. Broderip's species *Typhis coronatus* has long been an enigma, and not only its morphology but also its type locality have been misinterpreted. Enough specimens in various stages of the growth cycle have now been collected to establish its identity with *T. grandis*. The holotype, from Salango, "Colombia" (*i.e.*, the north side of Santa Elena Bay, Ecuador, not "Bay of Caraccas, Venezuela" as stated by Tryon), has been said to be a young specimen. This is not precisely correct. Rather, the specimen is a subadult, taken at a stage in the growth cycle just prior to the formation of a varix. The outer lip is somewhat broken, and the anterior face of the canal, which should be continuous, is broken away. In figure 17 a restoration is attempted, in dotted lines, from well-preserved specimens at the same stage of growth. A fully matured specimen is shown in figure 18. Young specimens up to five whorls show all of the characteristics of *Typhinellus* and might be mistaken for small adults of that subgenus. This suggests that *Typhisopsis* probably is derived from *Typhinellus*.

As in *Talityphis*, Cossmann misinterpreted the number of varices per whorl and subsumed *Typhisala* under *Pterotyphis*, an error which Thiele followed. Both Cossmann and Thiele placed *Typhisopsis*, however, in the synonymy of *Haustellotyphis*.

Species:

Typhis (*Typhisopsis*) "*coronatus*" (=*T.* (*T.*) *grandis*)

Typhis (*Typhisopsis*) *grandis*—Recent, Gulf of California

Typhis (*Typhisopsis*) *martyria* (=*T.* (*T.*) *grandis*)

Genus SIPHONOCHELUS Jousseaume, 1880

Siphonochelus JOUSSEAUME, 1880, p. 335.

Cyphonochelus JOUSSEAUME, 1882, p. 337. "Type, *Typhis arcuatus* Hinds" (1843).

Cyphonochilus JOUSSEAUME. COSSMANN, 1903-b, p. 61. [Unjustified emendation].

Trubatsa DALL, 1889, p. 216. Type (here designated): *Typphis* (*Trubatsa*) *longicornis* Dall, 1888.

Choreotyphis IREDALE, 1936, p. 324. Type (by monotypy): *Typhina* (*Choreotyphis*) *pavlova* Iredale, 1936.

Type (by original designation): "*Typhis avenatus* Hinds" = *Typhis arcuatus* Hinds, 1843.

Diagnosis: Varices and tubes four or more per whorl; varices obsolescent, with tubes soldered to posterior face of each.

Discussion: Due to the accidents of publication of Jousseaume's papers and the fact that he did not spell this generic name consistently, misunderstanding as to the proper form is frequent. Priority gives *Siphonochelus* precedence. Iredale, however (1924, p. 272), argues that the 1880 citation is a *nomen nudum* because there is no *Typhis avenatus* Hinds. There is a question as to whether a generic name, which otherwise conforms in its manner of proposal to conditions set up in the International Rules of Zoological Nomenclature, can ever be regarded as a *nomen nudum*. It might be a genus without species, the type of which would be the first species subsequently to be cited under it. But in this case, it seems to me, there is no need for devious interpretations. The mention of the author's name "Hinds" makes it possible to regard *avenatus* as a typographical error for *arcuatus* Hinds. The presence of a number of typographic errors in this paper is admitted by Jousseaume in the errata which he published.

[2] The International Commission on Zoological Nomenclature ruled in or before 1939 that "Article 36 of the Code applies only to primary homonyms and has no bearing whatever on secondary homonyms. Once therefore a secondary homonym is removed from the generic position that rendered it a homonym, it becomes once more the correct name for the species (or subspecies) concerned." (Quotation from a letter dated 24th January 1943 from the secretary of the Commission to Prof. T. D. A. Cockerell.) Therefore *Typhis coronatus* Broderip, 1883, is a valid name. EDITOR.

Subgenus SIPHONOCHELUS, *s. s.*

Diagnosis: Tubes and varices each four per whorl; tubes usually long; canal usually closed.

Species:

Siphonochelus (*Siphonochelus*) *arcuatus*—Recent, South Africa

Siphonochelus (*Siphonochelus*) *disjunctus*—Miocene, Australia

Siphonochelus (*Siphonochelus*) *duplicatus*—Recent, China Seas

Siphonochelus (*Siphonochelus*) *evaricosus*—Miocene, Australia

Siphonochelus (*Siphonochelus*) *fistulosus*—Pliocene, Italy

Siphonochelus (*Siphonochelus*) *gaasensis*—Oligocene, Belgium

Siphonochelus (*Siphonochelus*) *generosus*—Recent, Australia

Siphonochelus (*Siphonochelus*) *hortensis*—Eocene, Italy

Siphonochelus (*Siphonochelus*) *intergymnus*—Oligocene, France

Siphonochelus (*Siphonochelus*) *japonicus*—Recent, Japan

Siphonochelus (*Siphonochelus*) *longicornis*—Recent, Cuba

Siphonochelus (*Siphonochelus*) *parisiensis*—Eocene, England

Siphonochelus (*Siphonochelus*) *pavlova*—Recent, Australia

Siphonochelus (*Siphonochelus*) *rugicostatus*—Pliocene, Australia

Siphonochelus (*Siphonochelus*) *sejunctus*—Oligocene, Germany

Siphonochelus (*Siphonochelus*) *subtubifer*—Oligocene, France

Siphonochelus (*Siphonochelus*) *syringianus*—Recent, Australia

Subgenus LYROTYPHIS Jousseaume, 1880

Lyrotyphis "Bayle MS" JOUSSEAUME, 1880, p. 336; 1882, p. 338.

Type (by original designation): *Typhis cuniculosus* "Duchâtel" = *Murex cuniculosus* Nyst, 1836.

Diagnosis: Tubes and varices five or more per whorl; tubes short, appressed to preceding whorl; canal open.

Discussion: This group, which in certain respects superficially resembles both *Siphonochelus*, *s. s.*, and *Laevityphis*, *s. s.*, is always to be distinguished by the additional tubes and varices. The great variability attributed to the species *Siphonochelus* (*Lyrotyphis*) *schlotheimi* by Von Koenen, 1889, resulted from his confusion of three species, representing three genera in the present classification, as one. All of the specimens of the genotype which were examined in this study had five tubes per whorl; it is not unlikely that an occasional specimen may have six. Supposed specimens of *S. schlotheimi* with three and four tubes per whorl, figured by Von Koenen, appear to be *Pterotyphis* sp. and *Siphonochelus* (*Siphonochelus*) sp. instead. This subgenus is restricted to the Oligocene.

Species:

Siphonochelus (*Lyrotyphis*) *cuniculosus*—Oligocene, Belgium

Siphonochelus (*Lyrotyphis*) *schlotheimi*—Oligocene, Germany

Genus LAEVITYPHIS Cossmann, 1903

Laevityphis COSSMANN, 1903-b, p. 59.

Type (by original designation): *Typhis coronarius* Deshayes, 1865.

Diagnosis: Varices and tubes four per whorl; tubes nearer to succeeding than to preceding varices but not coalesced with varices; varices of moderate strength, sometimes with a spine at the shoulder.

Discussion: This genus was proposed by Cossmann as a "section" of *Typhis*, *s. s.* It is closely related to *Siphonochelus* and could plausibly be ranked as a subgenus. A few species are, in fact, with difficulty allocated to the one or the other. However, since the category *Indotyphis*, proposed below, seems subordinate to *Laevityphis* rather than to *Siphonochelus* and since *Laevityphis* seems to have appeared earlier, it is accorded generic rank here. As has been pointed out above, *Lyrotyphis* bears a certain resemblance to *Laevityphis* in the shape of its varices but may be easily distinguished by their number.

Subgenus LAEVITYPHIS, *s. s.*

Diagnosis: Tubes pointed outward or upward, never forward; varices often straplike.

Species:

Laevityphis (*Laevityphis*) *antiquus*—Eocene, California

(?) *Laevityphis* (*Laevityphis*) *cercadicus*—Miocene, Santo Domingo
Laevityphis (*Laevityphis*) *coronarius*—Eocene (Cuisian), France
Laevityphis (*Laevityphis*) *costaricensis*—Miocene, Costa Rica
Laevityphis (*Laevityphis*) *curvirostratus*—Oligocene, Mississippi
Laevityphis (*Laevityphis*) *gracilis*—Eocene, Alabama
Laevityphis (*Laevityphis*) *linguiferus*—Miocene, Florida
Laevityphis (*Laevityphis*) *muticus*—Lower Eocene, England
Laevityphis (*Laevityphis*) *sawkinsi*—Miocene, Trinidad
Laevityphis (*Laevityphis*) *sinuosus*—Eocene, France
Laevityphis (*Laevityphis*) *thagus*—Eocene, Peru
Laevityphis (*Laevityphis*) *transcurrens*—Recent, East Africa
Laevityphis (*Laevityphis*) *tubuliger*—Recent, East Africa
Laevityphis (*Laevityphis*) *vaquezi*—Eocene, France

Subgenus INDOTYPHIS Keen, n. subgen.

Type: *Laevityphis* (*Indotyphis*) *bantamensis* (Oostingh), 1933 = *Typhis bantamensis* Oostingh.

Diagnosis: Varices and tubes arranged as in *Laevityphis*, *s. s.*, except that the last tube is bent forward at a sharp angle and soldered to the back of the varix; varices not strap-like.

Species:
Laevityphis (*Indotyphis*) *bantamensis*—Plio-Pleistocene, Java
Laevityphis (*Indotyphis*) *patellifer*—Eocene, Java

Genus PTEROTYPHIS Jousseaume, 1880

Perotyphis JOUSSEAUME, 1880, p. 336.
Pterotyphis JOUSSEAUME, 1881, p. 367 (correction of *Perotyphis* as a typographical error); 1882, p. 338.
Trigonotyphis JOUSSEAUME, 1882, p. 338. Type, by original designation, *Typhis fimbriatus* A. Adams, 1854.

Type (by original designation): *Typhis pinnatus* Broderip, 1833.

Diagnosis: Varices and tubes per whorl three; sculpture present, usually of both axial and spiral riblets.

Discussion: The acceptance of Jousseaume's correction of the spelling "*Perotyphis*" as a typographical error (see footnote 1) might be questioned by one who insists upon a strict interpretation of Article 19 of the International Rules of Zoological Nomenclature: "The original orthography of a name is to be preserved unless an error of transcription, a *lapsus calami*, or a typographical error is evident." Jousseaume's 1880 paper being a simple list of generic names with designated type species, there is in the original publication only indirect evidence of his intention, if his own statement as to the error is rejected because of its later date. As evidence may be cited, first, his frequent use of generic names with the prefix *Ptero-* (*Pterochelus*, *Pteropurpura*, and even *Pteronotus* Swainson with *Murex pinnatus* Wood cited as type), whereas the prefix *Pero-* does not appear elsewhere in the paper. Secondly, the spelling *Ptero-* (wing) is meaningful and consonant with the root meaning of the name of the species selected as type, *pinnatus* (feathered). Although there is a Latin word *pero* (a kind of rough boot), its use here would seem meaningless. In analogous cases, the International Commission has accepted corrections of typographical errors (Opinions 26, 27). Moreover, adherence to a rigid legalistic interpretation in this case would lead to confusion rather than to stability, for authors subsequent to Jousseaume without exception have adopted the spelling *Pterotyphis*.

Subgenus PTEROTYPHIS, *s. s.*

Diagnosis: Tubes separate from but immediately preceding varices.

Species:
Pterotyphis (*Pterotyphis*) *fimbriatus*—Recent, Gulf of California
Pterotyphis (*Pterotyphis*) *pinnatus*—Recent, locality unknown

Subgenus TRIPTEROTYPHIS Pilsbry and Lowe, 1932

Tripterotyphis PILSBRY and LOWE, 1932, p. 78.

Type (by original designation): *Typhis* (*Tripterotyphis*) *lowei* Pilsbry, 1931.

Diagnosis: Tubes coalesced with varices, openings at tips of long spines.

Discussion: Further collecting may show that the distinction between *Tripterotyphis*

TABLE 1. ANALYSIS OF TYPE LOCALITIES OF TYPHINAE

Genus		*Typhis*						*Siphonochelus*		*Laevityphis*		*Pterotyphis*		
Subgenus / Age		*Typhis, s.s.*	*Typhina*	*Haustellotyphis*	*Typhinellus*	*Talityphis*	*Typhisopsis*	*Siphonochelus, s.s.*	*Lyrotyphis*	*Laevityphis, s.s.*	*Indotyphis*	*Pterotyphis, s.s.*	*Tripterotyphis*	*Semityphis*
Recent			West Africa Ecuador Australasia	Ecuador	Mediterranean Brazil Australasia(5) Japan	Gulf of California Unknown (probably Santo Domingo)	Gulf of California	Cuba South Africa Australasia(3) Japan China Seas		East Africa (2)		Unknown Gulf of California	Panama Caribbean	
Pleistocene														
Pliocene	U		South India		Florida	Costa Rica					Java			
	M										■			
	L	Italy						Italy Australia						?Australia
Miocene	U		Maryland			Florida								
	M		Florida (2) Panama		Jamaica Florida Tasmania	Santo Domingo (2)				Costa Rica Santo Domingo			Hungary	
	L	Italy			?New Zealand Australia (2) Java	California		Australia (2)		Trinidad Florida				
Oligocene	U	France						France Belgium						
	M							France Germany	Germany Belgium	Mississippi				
	L				Italy ?New Zealand									
Eocene	U	France England	Mississippi					Italy		Peru	Java			Java
	M	France						England		California Alabama France (2)				
	L									France England				

and *Pterotyphis, s. s.*, is fictitious or within the limits of variation of a single species. Some illustrations, at least, suggest this possibility.

Species:

Pterotyphis (*Tripterotyphis*) *"cancellatus"* (? = *triangularis*)—Recent, Caribbean

Pterotyphis (*Tripterotyphis*) *lowei*—Recent, Panama

Pterotyphis (*Tripterotyphis*) *"tripterus"* (= *wenzelidesi*)—Miocene, Europe

Subgenus SEMITYPHIS Martin, 1931

Semityphis MARTIN, 1931, p. 31.

Type (by monotypy): *Semityphis incisus* Martin, 1931.

Diagnosis: Tubes coalesced with varices, openings nearly flush with surface of shell; sculpture weak.

Species:

Pterotyphis (*Semityphis*) *incisus*—Eocene, Java

Pterotyphis (*Semityphis*) *"tripterus"*—?Pliocene, Australia

DISTRIBUTION OF THE TYPHINAE IN TIME AND SPACE

The distribution of the subgenera of the Typhinae is shown in tables 1 and 2. Table 1 shows the geologic and geographic distribution by type localities for some 85 species. Table 2 shows the total range in time of each of the subgenera, taking into account all published records.

Most of the subgenera originated in the early Tertiary. Only three are restricted to the Recent fauna. The earliest species as yet described is *Laevityphis muticus* (Sowerby), in the London clay of England (lower Eocene). Cossmann (1903-b, p. 57) reported an undescribed species from the Thanetian (Paleocene) which he considered to be *Typhis, s. s.* This record has not been documented by a published illustration. Reports of Typhinae in the Cretaceous seem to be based upon Gabb's description of *Laevityphis antiquus* from beds of Tejon age, now considered to be middle or upper Eocene, erroneously assigned to the Cretaceous by Gabb.

Three general regions are especially rich in fossil Typhinae—Australasia, the European basin, and the Caribbean basin. Certain of the species, such as *Typhis* (*Talityphis*) *alatus* and its varieties, seem to be good index fossils. In spite of the comparative rarity of specimens of Typhinae, stratigraphers may be able, with the aid of morphologic criteria outlined here, to use these fossils to advantage in correlation.

PHYLOGENY

According to Cossmann (1903-b, p. 8), the Typhinae originated at almost the same time as the Muricinae. Both subfamilies are branches of a family, the Muricidae, which developed very rapidly during the Eocene. Cossmann expressed the opinion that the Cretaceous ancestral stock of the family may be either the Fusidae or the Buccinidae, more probably the latter. Although the Muricidae are mentioned by several authors

TABLE 2. TIME RANGE OF THE SUBGENERA OF THE TYPHINAE

	Eocene			Oligocene			Miocene			Pliocene			Pleistocene	Recent
	L	M	U	L	M	U	L	M	U	L	M	U		
Laevityphis, s.s.	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Siphonochelus, s.s.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Typhis, s.s.	.	.	.	.	.	.	.	.	.	.				
Typhina		.	.	.	.	.	.	.	.	.	.	.	.	.
Indotyphis		.	.	.	.	.	.	.	.	.	.	.		
Semityphis		.	.	.	.	.	.	.	.	.	.			
Typhinellus				.	.	.	.	.	.	.	.	.	.	.
Lyrotyphis				.	.	.								
Tripterotyphis						?	.	.	.	.	.	.	.	.
Talityphis						?	.	.	.	.	.	.	.	.
Haustellotyphis														x
Typhisopsis														x
Pterotyphis, s.s.														x

as originating in the Cretaceous, I have been able to find no authenticated records beyond Cossmann's suggestion that one or two Danian (uppermost Cretaceous) species might be assignable to the family. Aside from these possible candidates, the first unequivocal Muricidae occur, apparently, in the Paleocene of Europe and India.

Paleocene Muricidae have cancellate sculpture somewhat like that of the present-day *Tritonalia* or *Ocenebra*, with a dozen or more axial ridges per whorl. Therefore, the Typhinae before the middle of the Eocene: (a) the tube may be more in advance of the varix, as in *Typhis, s. s.*, or (b) it may form simultaneously with the varix, as in *Siphonochelus, s. s.* A further migration of the tube backward in the *Typhis* stock produces *Typhinellus* (Oligocene) and its close relatives *Talityphis* (Miocene) and *Typhisopsis* (Recent). Similar relationships of tube to varix are observable in the trivaricate forms.

No Eocene species has heavy varices; this characteristic develops in late Oligocene or

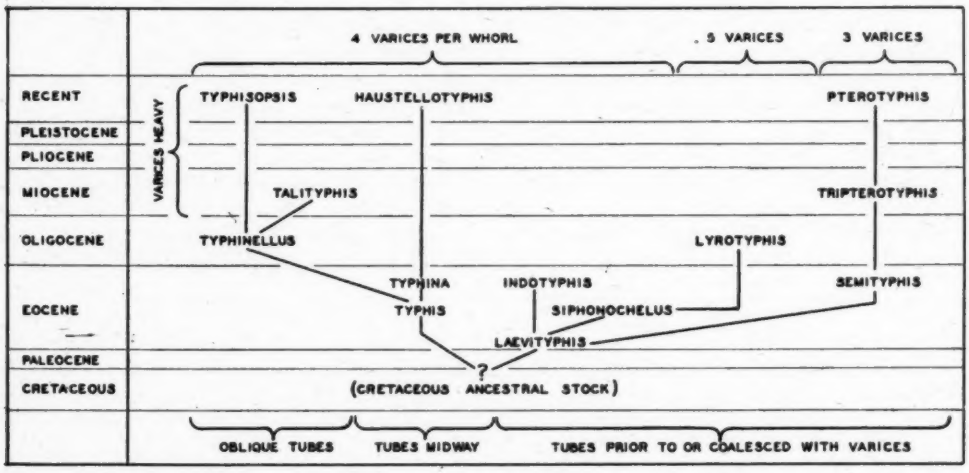


FIG. *20*—Presumed phylogeny of the subgenera of Typhinae.

consolidation of these into four varices spaced at regular intervals, as in the earliest typhine, *Laevityphis*, is an advance by reduction. This character is progressive, for a further reduction in one group occurs later, from four to three varices; an increase in number, achieved by one minor group, *Lyrotyphis*, was short-lived. Other morphologic characters in which progressive change takes place are: the relation of tubes to varices; the size of the final varix; and the length of the anterior canal.

In *Laevityphis* the formation of a tube is the first stage in the formation of a varix; each tube, in the finished shell, appears to be slightly in advance of each varix, separated from it by a small gap. There are, *a priori*, two alternative placements of the tube, both of which are achieved in the early Miocene time. Anterior canals of extreme length seem to be restricted to the Recent fauna, as also is loss of obliquity, seen in *Haustellotyphis*.

A phylogenetic chart based on these observations—which may, of course, be altered by further collecting—is given in figure 20.

CATALOGUE OF SPECIES

The following catalogue is arranged alphabetically by species, retaining the exact name combination used by the original author. Subsequent citations that give figures or other important data follow the statement of type locality. A complete list of figures, especially for such species as *Typhis tubifer*, the type of the genus, is manifestly out of the question; nor is it possible to decide upon the relative ranking or

synonymy of many species. Rather, this is an attempt to list as many as possible of the names that have been proposed. Probably it is too much to hope that all have been detected, for many obscure publications that have not received notice in bibliographic indices could not be canvassed.

The principal sources of names in this compilation have been the *Index Animalium* by C. D. Sherborn; The Zoological Record (London, 1864–1940); Geological Record (London, 1875–1882); Geological Literature (London, 1894–1936); Paleontologisches Zentralblatt (Leipzig, 1932–1933); Révue Critique de Paléozoologie (Paris, 1897–1924); International Catalogue of Scientific Literature (London, 1903–1916).[3] In addition, a few names were detected in synonymies and discussions of various species of *Typhis, s. l.*

In each entry the final item is an attempted allocation to generic or subgeneric unit. For the ranking of the latter the reader should turn to the systematic part of this paper. Allocations of many species are tentative because illustrations fail to show diagnostic characters clearly. An occasional species—indicated by a question mark—is represented by material so poorly preserved or figured that any guess as to relationships is unwise. To attempt a study of all holotypes, desirable as this is, or even to try ascertaining their repositories is, under present world conditions, impossible. Hence, many misinterpretations of species relationships are to be expected; however, the descriptions of classificatory characters in the systematic part of the paper should enable readers who have specimens at hand to correct the errors. A summary of material seen is included in this catalogue.

The following abbreviations are used for institutional collections: ANSP, Academy of Natural Sciences, Philadelphia; CAS, California Academy of Sciences (San Francisco); LSJU, Stanford University; UC, University of California (Berkeley); USNM, United States National Museum. Private collections mentioned in this summary are at present located as follows: S. S. Berry, Redlands, California; E. P. Chace, San Pedro, California; J. Wyatt Durham, Berkeley, California; H. G. Schenck, Stanford University.

Starred references have not been available to me for verification.

All information in brackets is interpolated from sources other than the original description.

Typhis acanthopterus Tate, 1888, p. 92, pl. 1, fig. 2. Blue clays, Schnapper Point, Port Philip Bay, Australia (older Tertiary) [lower Miocene]. ?TYPHINELLUS.

Murex acuticosta Conrad, 1830, p. 217, pl. 9, fig. 1. Maryland, Tertiary [Miocene]. Allocated to *Typhis* by Conrad, 1833, p. 344. Refigured, as *Typhis*, by Conrad, 1861, p. 83, pl. 48, fig. 1.—Conrad, 1868, p. 64, pl. 5, fig. 6.—Dall, 1890, p. 151,—Martin, 1904, p. 201, pl. 51, figs. 1–3, from Calvert and St. Mary's formations, Maryland. TYPHINA.

Typhis alatus Sowerby, 1850, p. 48, pl. 10, fig. 4. Tertiary [Miocene], Santo Domingo. One specimen seen, ANSP. TALITYPHIS.

Murex alternata Lea, 1833, p. 157, pl. 5, fig. 163. [Claiborne], Eocene, Albama. Figured, as *Typhis* (*Laevityphis*), Cossmann, 1903-b, p. 59, pl. 2, fig. 26. = *Typhis gracilis* Conrad.

Typhis angasi Crosse, 1863, p. 86, pl. 1, fig. 2 Port Jackson, Australia (Recent). Rejected from *Typhis* by Sowerby, 1866, p. 320. Not a *Typhis*.

Typhis antiquus Gabb, 1864, p. 82, pl. 18, fig. 31. "Cretaceous," Martinez, California [middle or upper Eocene]. Lectotype, ANSP no. 4335, refigured by Stewart, 1927, p. 387, pl. 27, figs. 7–8. LAEVITYPHIS.

Typhis arcuatus Hinds, 1843, p. 19. Cape of Good Hope, L'Agulhas bank in from 40 to 54 fathoms (Recent). Figured, Hinds, 1844, p. 10, pl. 3, figs. 1–2; refigured, Sowerby, 1866, p. 320, figs. 3–5—Sowerby, 1874, pl. 3, figs. 10a–c—Tryon, 1880, pl. 30, fig. 293. SIPHONOCHELUS.

"*Typhis arcuatus* Tenison-Woods, 1877, n. sp." Error in Zoological Record for a report of *T. arcuatus* Hinds in 10 fathoms of water off Long Bay, Tasmania by Tenison-Woods, 1877, p. 132 [probably a misidentification].

Typhis (*Typhinellus*) *bantamensis* Oostingh, 1933, p. 193, text-fig. 1. Pliocene, Java [possibly Pleistocene]. Five specimens seen, in collection of J. Wyatt Durham. INDOTYPHIS.

Typhis belcheri Broderip, 1833, p. 178. Cape Blanco [West Africa], Recent. Figured, Sowerby, 1941-a, pt. 200, figs. 5–6. Refigured, Sowerby, 1866, p. 320, figs. 8–9—Sowerby, 1874, pl. 2, fig. 9—Tryon, 1880, pl. 30, fig. 300. TYPHINA.

Typhis bivaricata Verco, 1909, p. 272, pl. 21, figs. 1–2. South Australia, 35 miles southwest of Neptune Islands, 104 fathoms (Recent). TYPHINA.

"*Murex cancellatus* Sowerby, 1841-b, p. 143. Habitat unknown (Recent). Figured, Sowerby,

[3] The dates cited here refer not to the time span covered by the publication in question but to the dates of volumes available for study in the present compilation.

1941-a, *Murex*, fig. 75; reprinted, Tryon, 1880, pl. 30, fig. 303. Refigured, Smith, 1939, p. 18, pl. 14, fig. 7, from Abaco, Bahamas. Homonym: not *M. cancellatus* Meuschen, 1787, Karsten, 1789, or Gmelin, 1790. ? = *Typhis triangularis* Adams? TRIPTEROTYPHIS.

Typhis cercadicus Maury, 1917, p. 265, pl. 42, fig. 12. Gurabo formation (Miocene), Santo Domingo. ?LAEVITYPHIS.

Murex (*Typhis*) *cleryi* Petit, 1840, p. 327. Cap Saint-Thomas (Brésil) par 40 brasses du profondeur, (Recent). Figured, fide Tryon, in Mag. Zool., 1842, pl. 54; figure reprinted, Tryon, 1880, pl. 30, fig. 301. Not *Typhis cleryi* Petit of Sowerby nor "*Typhis cleryi* Sowerby" of Tryon; see *Typhis philippensis* Watson. TYPHINELLUS.

Typhis coronarius Deshayes, 1865, p. 335, pl. 88, figs. 11–13. [Misspelled *T. coronatus* on plate explanation.] Cuise-la-Motte, Laon, sables inférieurs [i.e., Londinian or Cuisian, lower Eocene, France]. Figured, as *Typhis* (*Laevityphis*), Cossmann, 1903-b, p. 59, pl. 2, fig. 18. LAEVITYPHIS.

Typhis coronatus Broderip, 1833, p. 178, Salango, "Colombia [near Santa Elena Bay, Ecuador], 6 fathoms (Recent). Figured, Sowerby, 1841-a, pt. 200, figs. 3–4;—Sowerby, 1866, p. 320, figs. 6–7;—Sowerby, 1874, pl. 1, figs. 2, as "Bay of Caraccas (Colombia)" [Ecuador], which Tryon, 1880, p. 138, erroneously interprets as Venezuela. Transferred to *Murex* by Reeve, 1842, p. 194, pl. 240, figs. 3–4, making it a homonym of *M. coronâtus* J. Sowerby, 1819. = *Typhis grandis* A. Adams.

Typhis linguliferus costaricensis Olsson, 1922, p. 132, pl. 10. figs. 22, 29. Gatun formation, Miocene, Costa Rica. Figured, as *T. siphonifera* Dall, by Anderson, 1929, p. 138, pl. 9, fig. 8, from Miocene of Colombia. LAEVITYPHIS.

Typhis (*Talityphis*) *costaricensis* Olsson, 1942, p. 228, pl. 25, figs. 5, 8. Pliocene, mouth of Quebrada Peñitas, Burica Peninsula, Costa Rica. Homonym: *see Typhis* (*Talityphis*) *olssoni* **Keen.**

Typhis cumingii Broderip, 1833, p. 177. Bay of Caraccas, "Colombia" [Bahía de Caráques, Manta Bay, Ecuador], 7 fathoms (Recent). Figured, Sowerby, 1841-a, pt. 200, figs. 1–2;—Sowerby, 1866, p. 320. fig. 17;—Sowerby, 1874, pl. 1, fig. 4 a–b (fig. 4a reprinted, Tryon, 1880, pl. 30, fig. 298, as from "Bay of Caraccas, Venezuela"). Radula figured, Thiele, 1931, p. 293, fig. 318. Material seen: CAS coll., 3 specimens from near Acapulco, 13 fathoms, 2 from San José, Guatemala (+1, same locality, collection of Stillman Berry). HAUSTELLOTYPHIS.

**Murex cuniculosus* Nyst, 1836, p. 176, pl. 3, fig. 92 (fide Sherborn). Stampian and Tongrian [Oligocene] of Belgium, fide Cossmann. Allocated to *Typhis* by Bronn, 1848, p. 1340. Figured, as *Tiphys*, by Beyrich, 1854, p. 767, pl. 14, fig. 6 (Germany);—Speyer, 1863, p. 181, pl. 33, figs. 5–8 (Germany);—as *Typhis*, Wolff, 1897, p. 280, pl. 26, fig. 28 (South Bavaria);—as *Lyrotyphis* by Cossmann, 1903-b, p. 63, pl. 3, figs. 4–5 (Stampian, middle Oligocene, France);—as *Tiphys* by Ravn, 1907, p. 321, pl. 5, fig. 11 (Denmark). Material seen: three specimens, LSJU coll., two speciments, collection of Hubert G. Schenck, from upper Oligocene, Germany; two specimens, LSJU coll., from Stampian of France, middle Oligocene. LYROTYPHIS.

Typhis curvirostratus Conrad, 1847, p. 285. Newer Eocene [Byram marl, middle Oligoecne], Mississippi. Figured, Conrad, 1848, p. 116, pl. 11, fig. 29. Material seen: One specimen (topotype), LSJU coll. LAEVITYPHIS.

Typhis dentatus Johnson, 1899, p. 76, pl. 1, fig. 13. [Upper] Eocene, Jackson, Mississippi. TYPHINA.

Typhis disjunctus Tate, 1888, p. 92, pl. 1, fig. 1 (not 14, as stated). Lower beds at Muddy Creek, Hamilton, and blue clays at Schnapper Point, Port Phillip Bay, Victoria (Australia), Tertiary (lower Miocene). ?SIPHONOCHELUS (holotype probably a pathologic specimen).

Typhis duplicatus Sowerby, 1870, p. 251, pl. 21, fig. 1. China Seas (Recent). Reprinted, Sowerby, 1874, pl. 2, fig. 8 a–b (fig. 8b reproduced by Tryon, 1880, pl. 30, fig. 297, as *arcuatus* Hinds);—Sowerby, 1880, pl. 284-bis, figs. 29, 30. Figured, Nomura, 1935, pl. 161, pl. 8, fig. 5, Byôritu beds, Pliocene, Formosa. Holotype refigured, Yen, 1942, p. 223, pl. 20, fig. 138. SIPHONOCHELUS.

**Typhis eocenicus* Von Schauroth, 1865, p. 234, pl. 23, fig. 8 (fide Oppenheim, 1800). ?

Typhis evaricosus Tate, 1888, p. 94, pl. 1, fig. 6. Tertiary, lower beds at Muddy Creek (Victoria, Australia) [Balcombian stage, Miocene]. SIPHONOCHELUS.

Typhis expansus Sowerby, 1874-b, p. 719, pl. 59, fig. 4. Habitat unknown [probably Caribbean]. Refigured, Sowerby, 1874–a, pl. 3, fig. 12 a–b (fig. 12b reproduced by Tryon, 1880, pl. 30, fig. 306, as "*expansis*");—Sowerby, 1880, pl. 284-bis, figs. 24–25. Material seen: Four specimens from beach at Monte Cristi, Santo Domingo, collected by A. A. Olsson. TALITYPHIS.

Typhis fimbriatus A. Adams, 1854, p. 70. Gulf of California (Recent). Figured, Sowerby, 1874, pl. 1, fig. 3 (figure reproduced by Tryon, 1880, pl. 30, fig. 305 as *T. pinnatus*);—Sowerby, 1880, pl. 284-bis, fig. 28. PTEROTYPHIS.

Murex fistulosus Brocchi, 1814, p. 394, pl. 7, fig. 12 a–c. Fossile a Parlascio, alla Coroncina presso Siena e nel Piacentino [Pliocene, Italy]. Figured, Hoernes, 1856, p. 261, pl. 26, fig. 11, from middle Miocene, Hungary,—Misspelled *Typhis phistulosus* by De Stefani, *Pisa atti Soc. Toscany, vol. 23, 1907, fide Zoological Record. Figured as *Cyphonochilus* by Cossmann, 1903-b, p. 61, pl. 3, fig. 2;—Cossmann and Peyrot, 1924, p. 530, pl. 15, figs. 32–33, range stated to be Helvetian and Tortonian, France, Pliocene in Italy, Spain, and Austria. SIPHONOCHELUS.

Typhis floridanus Dall, 1889, p. 216. Pliocene, Caloosahatchee marl, Florida. Figured, Dall, 1890, p. 152, pl. 9, fig. 5. Material seen: 8

specimens, LSJU coll. (topotypes). TYPHINELLUS.

Typhis francescae Finlay, 1924, p. 465, pl. 49, figs. 6 a–b. ?Ototaran [?lower Oligocene], Clifden, Southland, New Zealand. TYPHINELLUS.

"*Typhis frondosus* J. Sowerby." Broderip, 1833, p. 178. ?Error for *Murex frondosus* Lamarck. Not a typhine.

Murex (*Trophon*) *fruticosus* Gould, 1849, p. 143. New Holland [Australia], Recent. Transferred to *Typhis* by Gould, 1862, p. 245. Figured, Gould, 1842, p. 236, pl. 17, figs. 287, 287a. Probably not a typhine.

Typhis sowerbyi fulva Pallary, 1906, p. 90. Sfax, Tunisia (Recent). Color variety of *T.* (*Typhinellus*) *sowerbyii*.

Cyphonochilus gaasensis Cossmann, 1903-b, p. 61, pl. 3, fig. 3 (*?ex* Tournouër Ms.). Oligocene, Gaas [Belgium]. Cited in text as "*Typhis gaasensis* Tournouër," a name which seems not to have been published by this author. SIPHONOCHELUS.

Typhis gabbi Brown and Pilsbry, 1911, p. 354, pl. 26, fig. 6. Gatun Miocene, Panama Canal Zone. TYPHINA.

Cyphonochelus generosus Iredale, 1936, p. 325, pl. 24, fig. 13. Off Green Cape, New South Wales, Australia, 70–85 fathoms (Recent). SIPHONOCHELUS.

Typhis gracilis Conrad, 1833, p. 344. [Gosport sand, Eocene], Claiborne, Alabama. Figured, Palmer, 1937, p. 271, pl. 36, figs. 1, 5; pl. 85, fig. 12. LAEVITYPHIS.

Typhis grandis A. Adams, 1855-a, p. 42, pl. 27, fig. 4. "California" [i.e., Gulf of California], Recent. Figured, Sowerby, 1874, pl. 1, fig. 1 a–b (fig. 1a reproduced by Tryon, 1880, pl. 30, fig. 306a);—Sowerby, 1880, pl. 284-bis, figs. 26, 27. Material seen: CAS coll., Arena Point, Lower California, 18 fathoms, one specimen; Cape San Lucas, one; Maria Madre Island, 5–10 fathoms, one; Tenacatita Bay, Jalisco, Mexico, one; Acapulco, Mexico, two (+one in collection of S. Stillman Berry); Santa Cruz Bay, Mexico, two; Oaxaca, Mexico, lat. 15° 40′ N., one. Range of species, San Pedro Mártir Island, Gulf of California, to Salango, Lat. 1° 40′ S., north side of Santa Elena Bay, Ecuador. TYPHISOPSIS.

Typhis harrisi Olsson, 1914, p. 46, pl. 9, figs. 7, 9. Alum Bluff formation, Miocene, Florida. Figured, Mansfield, 1930, p. 83, pl. 11, fig. 6, from Choctawhatchee formation, Miocene, Alum Bluff, Florida. TYPHINA.

Typhis hebetatus Hutton, 1877, p. 594, pl. 16, fig. 1. Mount Harris (Pareora formation), Canterbury, New Zealand [lower to middle Miocene, fide Singleton, 1941]. Considered to be a synonym of *Typhis m'coyi* Tenison-Woods by Suter, 1915, p. 28. TYPHINELLUS.

Murex horridus Brocchi, 1814, p. 405, pl. 7, fig. 17. Fossile a San Geminiano nel Sanese [Pliocene, Italy]. Figured, Hoernes, 1856, p. 260, pl. 26, fig. 9, Miocene, Hungary;—as *Typhis* by Cossmann, 1903-b, p. 57, pl. 2, fig. 24;—Cossmann and Peyrot, 1924, p. 526 (separate pagination), pl. 15, figs. 17–18, Miocene, France;—reported from Pliocene of Denmark, Ravn, 1907, p. 322; Miocene, Germany and Belgium by Kautsky, 1925, p. 99. See also *T. intermedius*. Material seen, 1 specimen, LSJU coll. TYPHIS.

Typhis hortensis Oppenheim, 1900, p. 221, pl. 15, figs. 7–8b. Via degli Orti (Italy), Priabonschichten [upper Eocene]. SIPHONOCHELUS.

Semityphis incisus Martin, 1931, p. 31, pl. 5, figs. 1, 1a. Axinaeaschichten, Kali Puru, Java (upper Eocene). SEMITYPHIS.

Typhis (*Cyphonochilus*) *intergymnus* Cossmann, 1919, p. 166, pl. 6, figs. 11–12. Oligocène, La Riverdiais (Rennes), France. SIPHONOCHELUS.

Typhis intermedius Bellardi, 1873, p. 40, pl. 4, fig. 1 (separate pagination). Dego a Cassinelle (Mio. inf.) [lower Miocene, Italy]. Figured, Cossmann and Peyrot, 1924, p. 528 (separate pagination), pl. 15, figs. 11–12, from Burdigalian (lower Miocene), France;—as *Typhis horridus* (Brocchi) by Montanaro, 1934, p. 10, pl. 1, fig. 1, from Montegibbio, Miocene, Italy. TYPHIS.

Typhis philippensis interpres Iredale, 1924, pp. 183, 271, pl. 34, fig. 10. Two-fold Bay, 15–25 fathoms, and Disaster Bay, New South Wales (Australia), Recent. TYPHINELLUS.

Murex jamrachi Von Martens, 1861, p. 225. Fundort unbekannt [possibly Panamic region]. = *Typhis fimbriatus* "Adams and Reeve" (i.e., A. Adams), fide Zoological Record for 1874.

Typhis japonica A Adams, 1863, p. 374. Uraga, Japan, 21 fathoms, Recent. SIPHONOCHELUS.

**Murex labiatus* Cristofori and Jan, 1832, p. 11. [Type locality not ascertained. = *Typhis fistulosus* (Brocchi), fide Bellardi, 1873, p. 42; = *T. tetrapterus* (Bronn) (*T. sowerbyii* Broderip), fide Kobelt, 1877, p. 287]. ?

Typhis laciniatus Tate, 1888, p. 93, pl. 1, fig. 10. Lower beds at Muddy Creek, near Hamilton, Victoria (Australia), [Balcombian stage, Miocene]. TYPHINELLUS.

Typhis (*Talityphis*) *lampada* Keen, 1943, p. 53, pl. 3, figs. 14, 19, 23, Lower to Middle Miocene, near mouth of Kern Gorge, Kern County, California. Material seen: holotype and paratype, LSJU coll.; paratype, CAS; 3 paratypes, UC. TALITYPHIS.

Typhis latipennis Fall, 1919, p. 339. Off Lower California, 24° 16′ N. lat., 110° 22′ W. long., 21 fathoms, sand (Recent). Figured, Smith, 1939, p. 18, pl. 14, fig. 9;—Keen, 1943, p. 53, pl. 3, figs. 17, 21, 24225. Material seen: holotype, no. 96653, USNM; two specimens from near type locality, CAS coll. TALITYPHIS.

Typhis linguiferus Dall, 1890, p. 152, pl. 12, fig. 7. Chipola River (Miocene), Florida. Recorded by Maury, 1925, p. 366, pl. 47, figs. 4, 5, from Machapoorie Miocene, Trinidad, a misidentification; see *L. sawkinsi*. LAEVITYPHIS.

Typhis (*Trubatsa*) *longicornis* Dall, 1888, p. 70, fig. 294. Off Havana, 127–400 fathoms (Recent). Refigured, Dall, 1889, p. 216, pl. 15, fig. 7; pl. 38, fig. 5;—Smith, 1939, p. 19, pl. 14, fig. 10. SIPHONOCHELUS.

Typhis lowei Pilsbry, 1931, p. 72. Montijo Bay, Central America [Panama], on reefs at extreme

low tide (Recent). Figured, Pilsbry and Lowe, 1932, p. 77, pl. 4, figs. 11, 11a;—Pilsbry, 1939, pl. 8, fig. 4. Material seen: two specimens, CAS coll., Tangola Tangola, Oaxaca, Mexico; one specimen, LSJU coll., Pleistocene near Puerto Angel, Oaxaca, Mexico. TRIPTEROTYPHIS.

Typhis macropterus Martin, 1883, p. 98, pl. 6, fig. 100. Ngembak (Miocene), Java. TYPHINELLUS.

Typhis m'coyi Tenison-Woods, 1876, p. 22, pl. 1, fig. 5 ("*mccoyi*" in plate explanation). Table Cape, Tasmania, fossil [Janjukian stage, lower to middle Miocene, fide Singleton, 1941]. Figured, Cossmann, 1903-b, p. 58, pl. 2, fig. 16, as *T.* (*Typhina*), from "Lower Oligocene," Australia. TYPHINELLUS.

Typhis martyria Dall, 1902, p. 550. Gulf of California, off San Pedro Mártir Island, 14 fathoms (Recent). Figured, Dall, 1908, pl. 15, fig. 11;—Smith, 1939, p. 19, pl. 14, fig. 6. Material seen: holotype, USNM. = *T.* (*Typhisopsis*) *grandis* Adams.

Typhis melloleitaoi Morretes, 1940, p. 251, pl. 1, figs. 1–3. Mocóca, Estado de São Paulo (Brazil) Recent. ?Young of *T.* (*Typhinellus*) *cleryi*.

Typhis sowerbyi minor Pallary, 1906, p. 90. Sfax, Tunisia (Recent). Probably = *T.* (*Typhinellus*) *sowerbyi* Broderip.

Typhis montfortii A. Adams, 1863, p. 374. Gotto, Japan, 48 fathoms; Okino-Sima, on the sands (Recent). Figured, Sowerby, 1866, p. 320, figs. 18, 19;—1874, pl. 3, fig. 15 (reprinted by Tryon, 1880, pl. 30, fig. 295). TYPHINELLUS.

Typhis muticus J. Sowerby, 1834, p. 247. [London Clay, lower Eocene,] England. Figured, as *Murex tubifer* Brug. by J. Sowerby, 1818, pl. 189, figs. 6, 7 (only);—as *Typhis*, Wrigley, 1930, p. 113, pl. 10, figs. 37, 38. LAEVITYPHIS.

Typhis nitens Hinds, 1843, p. 19. Straits of Macassar, Indian Archipelago, among coral and gravel in 18 fathoms (Recent). Figured, Hinds, 1844, p. 10, pl. 3, figs. 5, 6;—Sowerby, 1866, p. 319, figs. 1, 2;—Sowerby, 1874, pl. 2, figs. 6a–b; reprinted, Tryon, 1880, pl. 30, fig. 299. ?TYPHINELLUS.

Tiphis nystii d'Orbigny, 1852, p. 15, species no. 255′. Klein-Spauwen [Oligocene, Belgium]. New name for "*Murex tubifer* (Bruguière)" of Nyst. ?

Typhis obesus Gabb, 1873, p. 203. Miocene, Dominican Republic. Figured, Pilsbry, 1922, p. 354, pl. 28, figs. 5–6 (holotype, ANSP no. 3251);—as *T. alatus* by Olsson, 1922, p. 304, pl. 13, fig. 15, from Toro Cay, Panama, Miocene;—as *T.* (*Talityphis*) *alatus obesus* by Woodring, 1928, p. 294, pl. 18, figs. 3–4, Bowden formation, Miocene, Jamaica. [Specimens cited as *T. a. obesus* by Maury, 1925, p. 366, pl. 36, figs. 6, 9, from Manzanilla Miocene, Trinidad, probably represent an undescribed species.] Material seen: 1 specimen, Paleont. Research Inst.; 1, ANSP. 3, USNM. TALITYPHIS.

Typhis (*Talityphis*) *olssoni* Keen, 1943, p. 000. Pliocene, Costa Rica. New name for *T.* (*T.*) *costaricensis* Olsson, 1942, not Olsson, 1922. TALITYPHIS.

Tiphis parisiensis d'Orbigny, 1850, p. 364, no. 545. [Eocene, England or France]. Name for "*Murex pungens* Solander," 1766, (in part) pl. 3, fig. 82, and "*M. fistulosus* Brocchi" of Deshayes, 1835, p. 605, pl. 80, figs. 1–3. [N.B.: Before a type locality can be cited a lectotype from one of the figured specimens must be selected; if these are lost, a neotype must be designated.] Figured, as *Tiphys*, Von Koenen, 1889, p. 78, pl. 7, figs. 1–6 (lower Oligocene, Germany);—as *Typhis* (*Typhina*), Cossmann, 1903-b, p. 58, pl. 2, fig. 19 (Eocene, France);—as *Typhis*, Wrigley, 1930, p .113, pl. 10, fig. 40 (Eocene, England), SIPHONOCHELUS.

Typhis (*Typhinellus*) *patellifer* Martin, 1931, p. 31, pl. 4, figs. 16, 16a. Nanggulan beds, Upper Eocene, Netherlands East Indies. INDOTYPHIS.

Typhis pauperis Mestayer, 1916, p. 127, pl. 12, figs. 9, 9a. Poor Knight's Island, off New Zealand, 58–60 fathoms (Recent). TYPHINELLUS.

Typhina pavlova Iredale, 1936, p. 324, pl. 24, fig. 12. East of Sydney, New South Wales (Australia), 110 fathoms (Recent). SIPHONOCHELUS.

Typhis peyreirensis Cossmann and Peyrot, 1924, p. 235, pl. 16, figs. 34, 35. Aquitanian [upper Oligocene], Peyrère, France. TYPHIS.

Typhis phillipensis Watson, 1883, p. 605. Lat. 38° 22′ 30″ S., long. 144° 36′ 30″ E., off entrance to Port Phillip, Melbourne, 38 fathoms, sand (Australia, Recent). Figured, Watson, 1886, p. 162, pl. 10, fig. 4;—as "*T. cleryi* Petit" by Sowerby, 1866, p. 320, fig. 14 and 1874, pl. 3, fig. 11, fide Hedley, 1903, p. 382;—as "*T. cleryi* Sowerby" by Tryon, 1880, pl. 30, fig. 302;—Smith, 1939, p. 19, pl. 21, fig. 5; reported also by Hedley, 1907, Rec. Australian Mus., vol. 6, p. 289, from Tasman Sea in 80 fathoms. TYPHINELLUS.

Typhis phistulosus: see *fistulosus*.

Typhis pinnatus Broderip, 1833, p. 178. Recent (locality unknown). Figured, Sowerby, 1841-a, pt. 200, figs. 10, 11;—Sowerby, 1866, p. 320, figs. 15, 16;—Sowerby, 1874, pl. 2, fig. 7 (reprinted by Tryon, 1880, pl. 30, fig. 304). PTEROTYPHIS.

Typhis fistulosus var. *prisca* Rutot, 1876, p. 66, pl. 4, fig. 5a–b. À Grimmertingen et Neerepen [Belgium], à Latdorf, Helmstädt [and other localities, Germany], Oligocène inférieure. ? = *Siphonochelus sejunctus*.

Typhis (*Typhinellus*) *tetrapterus* var. *protetraptera* Sacco, 1904, p. 17, pl. 4, fig. 20. [Tongrian, Oligocene, Italy.] (*Nomen nudum* in Sacco, 1890, p. 239.) TYPHINELLUS.

**Typhis pseudo-fistulosus* Edwards, 1866, pl. 3, fide Wrigley, 1930. ? = *Siphonochelus parisiensis*.

Typhis pterinus Gardner, 1936, p. 52, pl. 10, fig. 10. Shoal River formation, Alum Bluff group, middle Miocene, Shell Bluff, Shoal River, Walton County, Florida. TALITYPHIS.

Murex pungens Solander, 1766, p. 35, pl. 3, fig. 81 (not 82—see *parisiensis*). [Barton beds, upper Eocene, England.] Figured, as "*Murex tubifer* (Bruguière)," J. Sowerby, 1819, p. 201, pl. 189, figs. 3–4;—Wrigley, 1930, p. 112, pl. 10, fig. 39.

Material seen: two specimens (topotypes), LSJU coll. TYPHIS.

Typhis quadratus Hinds, 1843, p. 18. Gulf of Nicoya and Bay of Guayaquil, 7–18 fathoms, mud [i.e., Panama and Ecuador], Recent. Figured, Hinds, 1844, p. 10, pl. 3, figs. 3–4; reprinted, Sowerby, 1866, p. 319, fig. 10; Sowerby, 1874, pl. 3, fig. 13; Tryon, 1880, pl. 30, fig. 296. TYPHINA.

Typhis (*Cyphonochelus*) *rugicostatus* Chapman and Crespin, 1933, p. 72, pl. 5, fig. 10. Kalimnan stage, lower Pliocene, East Gippsland, Victoria, Australia. SIPHONOCHELUS.

Typhis rutoti Cossmann, 1882, p. 125, pl. 6, fig. 7. Grignon, calcaire grossier moyen (i.e., middle Eocene, France). New name for "*Typhis tubifer* (Bruguière)" of Deshayes, 1835, pl. 80, figs. 4–6 (not pl. 82, figs. 26–27). TYPHIS.

Typhis sawkinsi Mansfield, 1925, p. 48, pl. 2, fig. 11. Machapoorie formation [i.e., Navarro River member, Brasso formation], middle or lower Miocene, Trinidad. Figured by Maury, 1925, pl. 47, figs. 4, 5 as *T. linguiferus* Dall. Material seen: one specimen from Brasso formation (topotype), LSJU coll. LAEVITYPHIS.

Tiphys schlotheimi Beyrich, 1854, p. 765, pl. 14, fig. 7a–c. Meklenberg, Segeberg, Steinbek [Upper Oligocene, Germany]. Figured, Wolff, 1897, p. 279, pl. 26, fig. 27;—Bajarunass, 1912, p. 45, pl. 3, fig. 3, Oligocene, Kertsch Peninsula, Russia. Material seen: six specimens, collection of Hubert G. Schenck, from Upper Oligocene of Germany. [See also under *sejunctus*.] LYROTYPHIS.

**Tiphys sejunctus* Semper, 1861, p. 116 (fide Speyer). [Upper Oligocene, north Germany]. Figured, Speyer, 1863, p. 182, pl. 33, figs. 9–11;—as *Typhis schlotheimi* by Von Koenen, 1889, p. 78, figs. 1–5 (not 6, which may be *wenzelidesi* or a new species);—as *Tiphys schlotheimi* by Ravn, 1907, p. 321, pl. 5, fig. 13, Oligocene of Denmark. Material seen: one specimen, upper Oligocene, Germany, Schenck coll. SIPHONOCHELUS.

**Murex* (*Typhis*) *simplex* Philippi, 1841, p. 26, pl. 4, fig. 22 (fide d'Orbigny) [Oligocene, Kassel, Germany]. = *Typhis cuniculosus* Nyst, fide Ravn, 1907.

Typhis sinuosus Cossmann, 1902, p. 133, pl. 11, figs. 25, 26. Loire (Eocene, France). LAEVITYPHIS.

Typhis (*Typhinellus*) *siphon* Woodring, 1928, p. 293, pl. 18, fig. 2. Bowden formation, middle Miocene, Jamaica. TYPHINELLUS.

"*Murex siphonellus* Bonelli" of Sismonda, 1847, p. 42: see *syphonellus*.

Typhis siphonifera Dall, 1915, p. 77, pl. 13, fig. 9. Tampa Silex beds "Oligocene" [Miocene], Tampa, Florida. Specimen figured by Anderson, 1929, pl. 9, fig. 8, from Miocene of Colombia as *T. siphonifera* is probably *Laevityphis costaricensis*. TYPHINELLUS.

Typhis sowerbyii Broderip, 1833, p. 178. Mediterranean (Recent). Figured, Sowerby, 1841-a, pt. 200, figs. 7–8;—H. and A. Adams, 1853, p. 76, figs. 2a–c (operculum and soft parts, reprinted by Tryon, 1880, pl. 30, figs. 290–291);—Reeve, 1860, p. 104, pl. 12, fig. 54;—Sowerby, 1866, p. 319, figs. 11–13 (fig. 13 reprinted by Tryon, 1880, pl. 30, fig. 292 as *tetrapterus*);—Sowerby, 1874, pl. 2, fig. 5a–c;—Smith, 1939, p. 19, pl. 14, fig. 12, as *T.* (*Typhinellus*) *sowerbyi*. Reported from Miocene and Pliocene' by Cossmann, 1903-b. Figured, as *T. fistulosus* (Brocchi), by Kiener, 1843, p. 124, pl. 6, fig. 4. Material seen: two specimens, LSJU coll., two specimens, collection of E. P. Chace. TYPHINELLUS.

Typhis subtubifer d'Orbigny, 1852, p. 76 (species no. 1398). Étage 26 [Aquitanian, upper Oligocene, Peyrère, France]. New name for *Typhis tubifer* "Lamarck" of Grateloup (not Bruguière), Grateloup, 1840, pl. 30, fig. 23. Figured, as *Cyphonochilus*, by Cossmann and Peyrot, 1924, p. 532 (separate pagination), pl. 15, figs. 26–27. SIPHONOCHELUS.

**Murex syphonellus* Bellardi and Michelotti, 1841, p. 129, pl. 3, figs. 3, 4 (fide Kobelt) [*ex* Bonelli MS]. = *Typhis tetrapterus* (Bronn), fide Kobelt, 1877. Probably a synonym of *T. sowerbyii*.

Typhis syringianus Hedley, 1903, p. 381, text-figure 94. Cape Three Points, New South Wales, Australia, 41–50 fathoms (Recent). Additional locality records by Hedley, 1907, Records, Australian Mus., vol. 6, p. 289, and Iredale, 1924, p. 273. SIPHONOCHELUS.

Typhis (*Typhinellus*) *tetragoniatus* Cossmann, 1903-a, p. 154, pl. 6, fig. 7. Pliocene, Karikal (French India). ?TYPHINA.

**Murex tetrapterus* Bronn, 1838, p. 1077, pl. 41, fig. 13 (fide Sherborn). [Pliocene, Italy.] Allocated to *Typhis* by Bronn, 1848, p .1340. Figured, as *Murex* (*Typhis*) by Hoernes, 1856, p. 263, pl. 26, fig. 10, from middle Miocene, Hungary;—as *Typhis* by Deshayes, 1864, pl. 113, figs. 4–6;—Cossmann, 1903-b, p. 60, pl. 3, fig. 1;—as *Typhis* (*Typhinellus*) by Cerulli-Irelli, 1911, p. 257, pl. 40, fig. 75, from Farnesina, Italy. = *Typhis* (*Typhinellus*) *sowerbyii* Broderip.

Typhis thagus Olsson, 1930, p. 58, pl. 12, fig. 6. Talara formation, upper Eocene, Peru. LAEVITYPHIS.

Typhis transcurrens Von Martens, 1902, p. 240. Zanzibar Canal, lat. 5° 27′ S., long. 39° 18′ E., 463–465 meters (East Africa). Figured, Von Martens, 1904, p. 94, pl. 3, fig. 2. LAEVITYPHIS.

Typhis triangularis A. Adams, 1855-b, p. 124. Locality unknown, Recent. ?TRIPTEROTYPHIS.

**Typhis tripterus* Grateloup, 1833, p. 160. [Miocene, France.] Figured, as *Murex* by Grateloup, 1847, pl. 2 (no. 30), fig. 22 (fide Sherborn). Not *Murex tripterus* Born, 1778. Figured, as *Typhis*, by Deshayes, 1864, pl. 113, figs. 1–3;—as *Pterotyphis* by Cossmann and Peyrot, 1924, p. 530 (separate pagination), pl. 15, figs. 13–14, from Burdigalian and Aquitanian, France. = *Pterotyphis wenzelidesi* (Hoernes).

"*Typhis tripterus*" Tate, 1888, p. 93, pl. 3, fig. 14. "Older Tertiary" [?Pliocene], clayey green sands, Adelaide bore, Australia. Homonym: should be renamed if authentic material is available. ?SEMITYPHIS.

Purpura tubifer Bruguière, 1792, p. 28, pl. 2, figs. 3–4. [Eocene, Paris Basin.] Figured, Montfort,

1810, p. 614, as *Typhis;*—Deshayes, 1864, pl. 113, figs. 7–9. TYPHIS.

Typhis tubuliger Thiele, 1925, p. 171, pl. 18 [30], fig. 18. Lat. 5° 28′ S., long. 39° 18′ E., in 463 meters (off Formosa Bay, East Africa), Recent. LAEVITYPHIS.

Typhis vaquezi Cossmann, 1906, p. 253, pl. 20, figs. 35, 37. Bois-Gouët [middle Eocene], France. LAEVITYPHIS.

Typhis harrisi waltonensis Mansfield, 1935, p. 38, pl. 5, fig. 9. Upper middle Miocene, Vaughan Creek, Walton County, Florida. TYPHINA.

Murex (*Typhis*) *wenzelidesi* Hörnes, 1856, p. 264, pl. 26, fig. 12a–d. Steinabrunn [middle Miocene, Hungary]. TRIPTEROTYPHIS.

Typhis yatesi Crosse and Fischer, 1865, p. 54, pl. 2, fig. 3. Golfe de St. Vincent (South Australia, Recent). Figured, as *yatesei*, by Sowerby, 1866, p. 319, figs. 20, 21 (fig. 20 reprinted, Tryon, 1880, pl. 30, fig. 294); as *yatesi* "Angas," Sowerby, 1874, pl. 3, fig. 14 and 1880, pl. 284-bis, figs. 22, 23;—Smith, 1939, p. 19, pl. 14, fig. 8. Material seen: one specimen Stillman Berry collection, from Australia. TYPHINELLUS.

**Typhis zealandica* Hutton, 1873, p. 2 [Wanganui formation, Pliocene]. Allocated to *Murex* (*Alipurpura*) *angasi* (Crosse) by Suter, 1914, New Zealand Paleo. Bull. no. 2, p. 2; allocated to *Pteronotus* (*Poropteron*) by Finlay, 1926, p. 419, pl. 19, fig. 56. Not a *Typhis*.

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The date following the author's name is the date of publication of the part of the book or paper (if issued in parts) in which the discussion of *Typhis* appears. It may or may not coincide with the date of issuance of the work as a whole; see, for example, "Deshayes, 1865." This date, 1865, refers to the date of livraisons 47, 48, in which *Typhis* is discussed (June 10, 1865), although the volume of which they are a part was not released, as a volume, until 1866. The notation "[1856] 1860–66" means that the first livraisons were published in 1856, the first volume of the set in 1860, the final volume in 1866.

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THE GENUS ATURIA IN THE TERTIARY OF AUSTRALIA

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ABSTRACT—*Aturia* occurs in Western Australia in a number of localities in deposits on the south coast and in the North-West District of the State. All occurrences belong to a new species, *Aturia clarkei*. This species is quite distinct from *Aturia australis* McCoy. The latter species, which is redescribed, is restricted to the Miocene of South Australia, Victoria, and Tasmania.

INTRODUCTION

THE PRESENT paper is primarily concerned with an account of Western Australian occurrences of the genus *Aturia;* but since Western Australian specimens have often been confused with the eastern Australian *Aturia australis*, it was found necessary to investigate in some detail the history and distribution of that species and also to give a revised description of *Aturia australis*, from which the Western Australian species could not have been differentiated on the basis of published information.

The results presented in this paper have only been made possible by a very lucky find made by Professor E. de C. Clarke in 1941 and by the generous coöperation of Dr. F. A. Singleton and Mr. George Baker, of Melbourne University, who placed some excellently preserved specimens of *Aturia australis* at my disposal, and of Mr. L. Glauert, who kindly lent some specimens of *Aturia* from the Plantagenet series that are kept in the collections of the Perth Museum. It gives me, therefore, great pleasure to record here my indebtedness to these gentlemen.

HISTORICAL NOTES ON ATURIA AUSTRALIS

The discovery of the genus *Aturia* in Australia is due to J. E. Woods (1862) who reproduced a fine woodcut of a nautiloid from Mount Gambier, South Australia, which he determined as *Nautilus ziczac*, but which undoubtedly represents the species which later became known as *Aturia australis*.

The name *Aturia australis* was coined by McCoy (1867, p. 192), but no description was given at that time beyond the statement that this was

> the most common and important of the fossil Cephalopoda [of Victoria], closely related to the *Aturia ziczac* of the lower Miocene and upper Eocene beds of Germany, France, and England.

The species was again mentioned by McCoy (1874, p. 36) in a list of Miocene fossils from Victoria, but no proper description of it was published until 1876. In that year McCoy (1876, p. 21) reduced the species to the rank of a variety of the Eocene *Aturia ziczac* (Sowerby), but peculiarly enough he states clearly in his description that

> it is with the compressed Miocene variety found at Dax, named *N. aturia* [*lapsus* for *aturi*] by Basterot, rather than with the more ventricose original types of the *N. ziczac* of Sowerby, proper to the Eocene London clay, that our Australian fossil more completely agrees.

He goes on to say that he

> can only doubtfully suggest the separation of it as a local variety,

stressing the greater compression of the whorls and the fact that the lateral lobe of the suture is more strongly curved. Although the close relationships between the Australian form and *Aturia aturi* were thus clearly stated, Etheridge (1878) listed the Australian species as "*Aturia ziczac*," with *Aturia australis* as a synonym.

The affinities of the species were again discussed by Foord (1891) who regarded *Aturia australis* as a variety of *Aturia aturi*, stating that the Australian specimens have a "larger siphuncular orifice," a feature which was not noted by McCoy.

Dennant and Kitson (1903, p. 94), resurrected *Aturia australis* as an independent species and later the same course was taken

by Chapman (1914, p. 208). The taxonomic position of the species was discussed in more detail by Chapman (1915, p. 351) when he was able to confirm McCoy's and Foord's observations regarding the distinguishing features of *Aturia australis*, which he concluded provided "justifiable grounds for keeping the Australian forms as a distinct species."

In the same year, however, Newton (1915, p. 375) stated his opinion that the Australian form "is not to be separated from the Miocene species of Europe known as *Aturia aturi*"; he mentions that this view was being supported by Crick, the eminent authority on Mesozoic and Cenozoic nautiloids in England. A few years later Newton (1919) described a specimen of *Aturia* from the south coast of Western Australia, which he referred without reservation to the European *Aturia aturi*, stating that it was also identical with the species that had been described as *Aturia australis* from Victoria and South Australia. Newton's Western Australian specimen was not very well preserved, and the author fails to make detailed comparisons between this specimen and specimens from eastern Australia and from Europe.

The question was again discussed in detail by Chapman in 1921, who maintained the validity of the differences between the Australian form and *Aturia aturi* that had been stated by McCoy, Foord, and himself, although he admits that the larger siphuncular orifice, first mentioned by Foord, is "not an invariable character." However, in his opinion, the compressed and generally narrower sides are marked characters of the Australian specimens that serve to distinguish them perfectly well from the European *Aturia aturi*, which "tends towards obesity."

Chapman's conclusions seem to have been generally accepted by Australian palaeontologists, for since 1921 *Aturia australis* seems always to have been listed as an independent species, although no further observations or descriptions of the species have been published; but in 1941 (p. 431) Miller regarded it as very doubtful if *Aturia australis* can be distinguished from typical *Aturia aturi*.

CHARACTERISTICS AND AFFINITIES OF ATURIA AUSTRALIS

Thanks to the kindness of F. A. Singleton and George Baker, of Melbourne University, I have been able to examine a number of specimens of *Aturia australis* ranging from 18.5 to 92 mm. in diameter. Since existing descriptions of the species are not sufficient to differentiate it from others and in particular from the Western Australian *Aturia* I have drawn up the following description:

Shell involute, compressed, large. Diameter of a normal mature phragmocone apparently in the vicinity of 90 to 100 mm.; largest specimen on record (with living chamber?) about 175 mm. diameter. The whorls are compressed, flattened laterally, rather narrowly rounded ventrally, and deeply impressed dorsally. The flanks of the whorls diverge at an angle of between 20° and 25° and throughout all stages of growth have a shallow impressed zone near the ventrolateral shoulder. Although this zone is very shallow, the effect of this flattening of the flanks on the general shape of the conch is quite perceptible and makes the shells look more slender than they actually are.

As in most species of *Aturia* the maximum width of the conch is attained just ventrad of the umbilical shoulders. The width of the whorls is generally from two-thirds to more than four-fifths of their height; mature whorls seem to be proportionally broader. Umbilicus small and closed with callus. Growth lines on the shell clearly visible; they form broad and prominent lateral saddles and a deep and narrow ventral lobe.

Although the septa are fairly close together as is typical for the genus, yet the sutures hardly ever touch. The most characteristic feature of the septa is the fact that they have a strong convexity just ventrad of the siphuncle. The septum, instead of sloping ventrad and backward from the siphuncular orifice (or septal foramen), slopes first ventrad and forward and then backward so as to form the normal concavity. In this way an infundibuliform cavity is formed, which extends backward into

the septal funnel that surrounds the siphuncle. In a median section (pl. 16, fig. 3) the septa, therefore, appear to be sickle-shaped.

Each suture (fig. 2) forms a high, broad lateral saddle on each flank, which culminates at a point approximately one-third the distance from the umbilicus to the venter and then swings backward in one broad and even curve as far as the apex of the lateral lobe. There is thus no perceptible change in the degree of curvature at the transition from the ventral flank of the saddle to the umbilical flank of the lobe, and the suture forms one entire and unbroken curve from the umbilicus to the apex of the lobe. The lobe is acutely pointed, and its ventral side rises steeply, keeping approximately parallel to the curvature of the ventral side of the conch. It rises only to little over half the height of the lateral saddle, turns abruptly ventrad and crosses the venter in an almost straight line.

The siphuncle is rather small; its diameter is equal to something like one-fifteenth of the diameter of the conch. It is encased in long septal funnels extending backward from each septum to the immediately preceding septum, where they continue into the infundibuliform portion that is formed by the forward convexity of the septum near the siphuncular orifice. It is undoubtedly this infundibuliform portion of the septum that Foord mistook for a large siphuncular orifice.

Following are the measurements of some specimens at various stages of growth. Unfortunately I have been unable to study any specimens with living chamber preserved, and all the measurements in the table are taken from phragmocones only.

The material at my disposal is inadequate to allow me to enter into a detailed discussion of the relationships of *Aturia australis* and *Aturia aturi*. Most of the papers containing descriptions and figures of the European species are inaccessible to me, but judging from figures and descriptions published by Bronn (1838), Edwards (1849), Foord (1891) and Schenck (1931), it is hard to find very striking and obvious differences. The small specimen of *A. aturi* that Bronn (1838, pl. 47, fig. 17) figures is externally indistinguishable from small specimens of *A. australis* from Muddy Creek. The more mature specimen of *A. aturi* figured by Foord (1891, p. 336) is not more obese than specimens of *A. australis* of the same size; even the slightly impressed zone on the flanks close to the ventrolateral shoulders is

	Maximum diameter (mm.)	Height of last preserved zone (mm.)	Height of same whorl above impressed zone (mm.)	Maximum thickness (mm.)	Ratio of thickness to diameter	Ratio of thickness to height of last whorl	Angle formed by flanks
F. A. Singleton's collection (smallest specimen).	18.5	11.5	7	9	0.50	0.78	25°
Melbourne University collection. Specimen from Point Ronald.	48.5	34.5	19	21.5	0.44	0.60	20°
Dept. Geology, University of W.A. No. 15987. Pl. 14, figs. 3, 4	81	?	?	33.5	0.41	?	25°
F. A. Singleton's collection (largest specimen). Pl. 14, figs. 1, 2	92	55	35	46	0.50	0.84	25°
McCoy, 1876, pl. 24, fig. 3.	53	33	18.5	23	0.43	0.70	
Foord, 1891, p. 336, *A. aturi*.	65	38	21	30	0.46	0.79	

present in *A. aturi*, and few specimens of *A. australis* are apparently as slender as the one figured by Chapman (1921, p. 13). Also, the sutures of various specimens of *A. aturi* as reproduced by Schenck (1931, fig. 4) are very similar to the suture of *A. australis* in their mode of curvature of the lateral saddle and in the shape and size of the lateral lobe.

It is possible that the only real difference between the two species will be found in the longitudinal median section of their septa. To judge from a rather crude figure published by Edwards (1849, pl. 9, fig. 2) of a specimen determined as *Aturia ziczac* but actually representing *A. aturi*, the septa in that species slope backward in the vicinity of the septal foramen and are not bent forward as in *Aturia australis*.

Whatever the relationships may be between *A. aturi* and *A. australis*, the description of *A. australis* as given above will enable one to distinguish clearly between this species and other representatives of the same genus from Australia and the southwestern Pacific area.

— RANGE AND DISTRIBUTION OF ATURIA AUSTRALIS

In 1915 Chapman gave the stratigraphical range of *Aturia australis* as Oligocene to lower Pliocene, but it appears from more recent observations (Singleton, 1941) that beds with *Aturia australis*, some of which were then regarded as Oligocene and others as lower Pliocene, are now all included in the Miocene. This refers particularly to the occurrences at Muddy Creek and to the Beaumaris beds, so that the range of *Aturia australis* is undoubtedly the same as that of *Aturia aturi* in Europe, that is Miocene.

A report of the occurrence of the species on the Gellibrand River in Victoria, low down in the Tertiary series (Chapman, 1915, p. 353), very probably refers to specimens of the genus *Aturoidea*, as has been explained elsewhere (Teichert 1943).

The regional distribution of *Aturia australis* is undoubtedly much more restricted than might appear from a mere perusal of published fossil lists. It will be shown in this paper that the species is apparently unrepresented in Western Australia. It also appears unlikely that the species occurs in New Zealand, where it has often been reported. Suter (1921, pp. 41, 55, 79) lists *Aturia australis* from various localities in the South Island of New Zealand, all apparently from beds of Oligocene age, but according to Marwick (see Schenck, 1931, p. 439) the genus *Aturia* has been found in New Zealand in Eocene, Oligocene, and Miocene rocks. However, no description of any New Zealand forms has ever appeared, although Hamilton (1904) figured one specimen under the name of *Aturia ziczac* var. *australis*. The large size of the specimen (15–16 inches) immediately arouses suspicions that it might not be identical with typical *Aturia australis* of which the largest specimen recorded so far measures 7 inches in diameter (Chapman, 1921, p. 13). Much more important, however, is the fact that the septa of the New Zealand specimen are in their median section quite unlike those of *Aturia australis* which, as has been shown above, are distinctly sickle-shaped. Although no other distinctive features can be observed in Hamilton's figures, the shape of the septa, if not the size of the specimen, should exclude it definitely from any association with *Aturia australis*. Until undisputable specimens of *Aturia australis* have been described from New Zealand, reports of the occurrence of the species in New Zealand deposits should be treated with caution.[1]

[1] It is interesting in this connection, to note that Marwick in 1924 compared 25 fossil mollusk species which at different times had been claimed to be common to Australia and New Zealand and found that specific identity could only be definitely upheld in one case. With regard to the species which he could not review and which, unfortunately, included *Aturia*, he stated that "it is likely that most of them also will have to be differentiated."

EXPLANATION OF PLATE 14

FIGS. *1–4*—*Aturia australis* McCoy. Miocene, Muddy Creek, Victoria, ×1. *1*, *2*, F. A. Singleton's collection, Melbourne; *3*, *4*, Univ. Western Australia, Dept. Geology, no. 15987. (p. 76)

1

2

3

4

Aturia australis McCoy

1 2

3 4

Aturia clarkei Teichert, n. sp.

A specimen from the Tonga Islands which Miller in 1941 described under the name of *Aturia* cf. *aturi* differs from *A. australis* perceptibly in the much broader lateral lobe of its suture, which culminates about halfway between the umbilicus and the venter, and in the division of the umbilical lobe into three secondary lobes. The unnamed *Aturia* from Java described by Durham in 1940 has a much broader cross section and is altogether different.

It seems then that as far as available observations allow one to judge, *Aturia australis* is restricted to the southeastern portion of Australia (text fig. 1), where it is found in Miocene beds of southeastern South Australia, southwestern Victoria, and northern Tasmania.

FIG. 1—Distribution of *Aturia* in Australia. Simple hatching, *Aturia australis;* cross hatching, *Aturia clarkei.*

ATURIA IN WESTERN AUSTRALIA

The first mention of the occurrence of an *Aturia* in Western Australian rocks was made by Jutson and Simpson in 1916 (p. 24), when they reported the finding of "*Aturia australis*" in the vicinity of Albany, near the south coast of the State, in beds of Tertiary age for which they proposed the name Plantagenet series. In 1917 the same authors published some additional information regarding the occurrence of the same species and stated that it had been found at Cape Riche and on the Bremer River, some 50 and 100 miles respectively from Albany eastward along the coast.

A few years later Newton (1919) described a specimen of an *Aturia* which had been obtained in the same general region and which he referred to the European species *Aturia aturi*, stating that he regarded *A. australis* as a synonym. Since then, the presence of *Aturia* in the Tertiary beds of the south coast was again noted by Chap-

EXPLANATION OF PLATE 15

FIGS. 1–4—*Aturia clarkei* Teichert, n. sp. Kennedy Range, North-West Division, Western Australia, ×1. *1*, Paratype, no. 21407e; *2*, holotype, no. 21406; *3*, *4*, paratype, no. 21407a. Univ. Western Australia, Dept. Geology. (p. 79)

man and Crespin in 1934, who listed *Aturia australis* from the brick works, 3 miles northeast of Albany. Incidentally, Chapman and Crespin confirmed the Miocene age of the Plantagenet series, which had already been suspected by Jutson and Simpson. Unfortunately, the only detailed description of any *Aturia* from these strata is the one published by Newton in 1919, and his specimen was rather fragmentary. Schenck (1931, fig. 46) attempted to reconstruct the suture of this specimen from Newton's figures.

More recently, the discovery of a representative of the same genus approximately 750 miles farther north was announced by Condit, Raggatt, and Rudd (1936, p. 1059), who stated that a specimen of *Aturia* had been found 2 miles northeast of Merlinleigh Woolshed, east of the Kennedy Range, in the Northwest Division, approximately 75 miles north of the Gascoyne River. The occurrence seemed very puzzling at the time, since this locality is situated in country that, as far as then known, was composed entirely of Permian strata and was situated 90 miles inland from any known outcrop of Tertiary age. A description of the specimen by Miller and Crespin followed in 1939. These two authors hesitated to attach any definite name to the specimen, but stated that it was apparently related to *Aturia ziczac* and at any rate seemed to have nothing to do with the Victorian *Aturia australis*.

While Condit, Raggatt and Rudd regarded it as "quite possible" that the specimen has been "derived from the disintegration almost *in situ* of a Tertiary (Eocene-Miocene) deposit," Singleton (1941, p. 57), when discussing the significance of this find for the Tertiary palaeogeography of Western Australia, cautions the reader that the discovery of this important fossil "is vitiated by a doubt as to whether the specimen may not have been transported by human agency."

Luckily in April 1941 some further finds were made in the same general region which shed new light on the occurrence of *Aturia*. At that time, the writer traversed this country in the company of Professor E. de C. Clarke and two students of the University of Western Australia. While travelling along the eastern scarp of the Kennedy Range north of Merlinleigh Homestead, Professor Clarke found a fragment of a large *Aturia* sticking in the sand of the flood plain at the foot of the scarp. Immediate search of the vicinity of this place by our party yielded a number of additional fragmentary specimens of the same genus, in addition to some corals and pelecypods. All the specimens were found loose in the alluvial sand, and since the party was bound for a more northerly destination, no attempt could be made to locate the original outcrop from which these specimens must have been derived.

The escarpments from which the specimens must have been washed down consist of sandstones of Permian age, while the nearest deposits of Tertiary age at present known crop out about 90 miles west of this locality. There is, however, no question that future field work will reveal the existence in the Kennedy Range of Tertiary beds, from which the specimens collected by us near Merlinleigh have been derived. Miller and Crespin's specimen of *Aturia* cf. *A. ziczac* from "2 miles northeast of Merlinleigh Woolshed" must have been found a few miles southeast of this new locality.

The new specimens make possible a more detailed description of this form, which has turned out to be a new species, here named *Aturia clarkei*.

The associated fauna consists of *Latimaeandrina* sp., *Astrocoenia?* sp., *Glycimeris* sp., *Chione?* sp., and *Chama* sp., none of which furnished any clue as to the place of this fauna within the Tertiary system.

THE DISTRIBUTION OF ATURIA CLARKEI AND THE QUESTION OF THE MIOCENE SUBMERGENCE IN WESTERN AUSTRALIA

The detailed description of *Aturia clarkei* below will make it clear that all Western Australian occurrences of *Aturia* belong to that species, and, until evidence to the contrary is forthcoming, it is reasonable to assume that the beds in which that species occurs in various parts of the State are all of more or less the same age. Chapman and Crespin (1934) determined the age of the Plantagenet beds of the south coast as lower

Miocene, and a Miocene age can, therefore, also be assumed for the *Aturia* beds of the Kennedy Range.

The Miocene is an important period in the history of Western Australia, for it has long been suspected that considerable parts of the Western Australian shield were submerged below sea level during this time. The discussion of the extent of the Miocene transgression has so far mainly been concerned with the southern part of the State. Jutson (1934, pp. 182–195) has presented an excellent summary of this question, which is closely connected with the problem of the origin of the Great Plateau of Western Australia. It appears that while the probability of a widespread transgression of the sea across the southeastern plateau in relatively late geological times has long been recognized (compare in particular Montgomery, 1917), Gregory (1914) was the first to suggest that this transgression might have taken place during the Miocene. In 1916 Gregory was able to support this suggestion by demonstrating a probable Miocene age of the Norseman limestone, which occurs at an elevation of 900–1,000 feet above sea level more than 100 miles inland from the south coast. After Jutson and Simpson, in 1917, had suggested a probable Miocene age for the fossiliferous deposits (Plantagenet beds) of the south coast, a view which received further support by the palaeontological studies of Chapman and Crespin (1934), Clarke, in 1935, summarized the position with regard to the "Miocene submergence" as follows:

> At the close of the early Kainozoic peneplanation, the land sank uniformly and slowly beneath the Miocene sea. . . . When submergence had reached its maximum, the present land surface stood 1,500 or 2,000 feet below its present level. We seem justified in assuming that the site of Norseman was in Miocene times at least 600 feet below the sea. But Norseman is now about 900 feet above sea-level, and therefore such submergence would, unless it were accompanied by warping, lead to the submergence of most of the State as far north as Leonora. Long inlets probably reached farther north. This amount of submergence is probably a minimum.

While an advance of the sea from the south over a belt of about 350 miles was thus considered a strong possibility, Montgomery had, as early as 1908, postulated a marine origin of the peneplain of the old Pilbara block, a further 500 to 600 miles to the north, in the northwest of Western Australia, although he did not discuss the time of the transgression in that region. In view of these possibilities the absence of Tertiary deposits at any appreciable distance from the west coast of Western Australia must always have seemed peculiar. However, the discovery of Miocene fossils in the Kennedy Range, 100 miles inland from the shores of the Indian Ocean, is sufficient to indicate a considerable advance of the sea from that direction. The fauna of nautiloids, pelecypods and corals suggests an open shallow sea and makes it seem unlikely that the beds have been deposited in a narrow local embayment or inlet which might have extended inland from the coast.

If the Tertiary deposits in the Kennedy Range lie, as may be assumed, somewhere in the higher parts of the range, their elevation above sea-level must be in the vicinity of 1,100 or 1,200 feet. At the time of the deposition of the beds the place must have stood more than 1,200 feet, probably 1,500 feet or more, below its present level. This figure agrees surprisingly well with that calculated for the submergence of the Norseman area by Clarke.

DESCRIPTION OF THE WESTERN AUSTRALIAN ATURIA CLARKEI

ATURIA CLARKEI Teichert, n. sp.

Plate 15, figures 1–4; plate 16, figures 1, 2; text figure 2

Aturia aturi (Basterot). NEWTON, 1919, Malac. Soc. London Proc., vol. 13, p. 160, pls. 5, 6.

Aturia cf. *A. ziczac* (Sowerby). MILLER and CRESPIN, 1939, Jour. Paleontology, vol. 13, no. 1, p. 80, pl. 14, fig. 1.

Description.—Very large species; the largest specimen is a fragmentary and somewhat crushed phragmocone whose original diameter must have measured more than 20 cm.; complete with living chamber the diameter of that specimen can hardly have been less than 30 cm. and was probably greater. The conch is strongly involute and compressed; the umbilicus is filled with callus. The whorls are deeply impressed dorsally, have almost flat flanks, which diverge at an angle of about 30°, and a broadly rounded venter.

The following measurements have been taken from the holotype which is a part of a phragmocone only: diameter, 90 mm.; width, 42 mm.; height of last preserved whorl, 56 mm.; height of that whorl above impressed zone, 36 mm.; angle of divergence of flanks, 30°; ratio of width to diameter, 0.47; ratio of width to height of last whorl, 0 75.

Other specimens are unfortunately not in a state of preservation which would allow the taking of exact measurements.

more narrowly curved deeply indented ventral lobe.

The siphuncle is rather large; its diameter equals approximately one-eleventh to one-twelfth of the diameter of the conch. It is encased in a solid tube formed of septal funnels that extend backward from each septum to and only very little beyond the immediately preceding septum.

The central portions of the septa are evenly, though not very strongly, concave. In the median cross section they swing back-

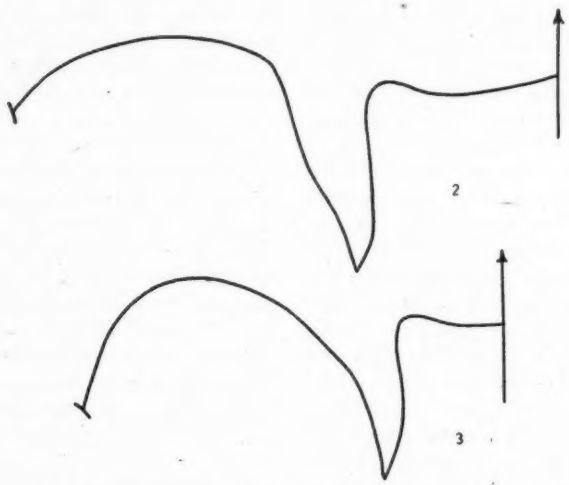

FIG. 2—External suture of *Aturia clarkei* Teichert, n. sp. Holotype. Kennedy Range, Western Australia.
3—External suture of *Aturia australis* McCoy. Miocene. Muddy Creek, Victoria. No. 15987, Department of Geology, University of Western Australia.

The flanks on the whole are very slightly convex, particularly along their umbilical part, or, more accurately, between the umbilicus and a place approximately two-thirds the distance between the umbilicus and the venter. Here a very slight flattening of the flanks may take place, although it is apparently not present in all specimens, and there is at any rate no indication of any impressed zone in this region. Rather, the angle of divergence of the flanks increases very slightly until the ventrolateral shoulders are reached, where the conch curves ventrad in a broad and even curve.

The outside of the shell shows distinct, closely-spaced, growth lines, which form a strongly curved broad lateral saddle and a

ward in an even curve from the septal foramen. They are set well apart, so that successive sutures never touch.

The external suture (text fig. 2) forms one broad, asymmetrical saddle on each flank. The umbilical limb of this saddle rises with low convexity from the umbilicus until the point of culmination approximately in the middle of the flank of the whorl; it then curves downward somewhat suddenly and rather steeply and passes into the steep, slightly bulging dorsal limb of the lateral lobe. This lobe is large, long, acute, and somewhat drawn out at its apex. Its ventral limb rises steeply, is slightly curved so as to run approximately parallel to the curvature of the ventral side of the conch. It rises

to not less than three-fourths of the height of the lateral saddle. The suture then curves abruptly ventrad and slightly backward, forming a shallow, narrow ventrolateral depression, and crosses the venter in a broad and very shallow saddle.

This description is based on the holotype and paratypes from the type locality in the Northwest Division. The specimen described as *Aturia* cf. *A. ziczac* by Miller and Crespin in 1939 was found not very far away from that place. On account of the shape of its conch and the very characteristic course of its suture it must be placed in the same species.

Specimens from the Plantagenet series.—I have been able to examine two rather large fragments of specimens from the Plantagenet series of the south coast of Western Australia, both in the Perth Museum and Art Gallery, which undoubtedly belong to the same species. One specimen (no. G6063) from Narrikup, Western Australia, represents parts of seven chambers of a phragmocone (pl. 16, fig. 9). The whorl must have been at least 120 mm. high and the size of the original specimen roughly equal to that of the largest specimen from the type locality. Its depressed zone is about 55 mm. deep, and the original width of the whorl, though hard to estimate, may have been in the vicinity of 80 mm. The lateral saddles and lobes of the suture can be examined and as far as can be told from them the sutures are identical with those of the typical *Aturia clarkei*. Also, the central portion of the septa is concave and in the median cross section the septa describe a shallow concave curve.

Another specimen from the Plantagenet series (no. F278) represents an internal mould of part of a living chamber. This specimen has been strongly crushed laterally, and the original cross section of the living chamber cannot be reconstructed. The bottom of the living chamber, indicating the course of the last suture, measures 80 mm. dorsoventrally. The suture has the outline that is typical for *Aturia clarkei:* an asymmetrical lateral saddle, a long, drawn-out lateral lobe with steep sides, and a ventrolateral saddle about three-fourths as high as the lateral saddle. This specimen is rather similar to the one described from the same general area by Newton in 1919, which also shows the characteristic suture of *Aturia clarkei* and must undoubtedly be referred to that species.

The species has been named in honor of E. de C. Clarke.

Occurrences.—Northwest Division: The holotype (No. 21406, Dept. Geology, Univ. Western Australia) and five paratypes (Nos. 21407a, b, c, d, e) were found on the track following the eastern scarp of the Kennedy Range, 1.3 miles north of the breakaway that leads up to Merlinleigh Homestead, on the alluvial flood plain, but undoubtedly derived from sandstone deposits higher up in the Kennedy Range. Another specimen had previously been found somewhat farther east, about two miles northeast of Merlinleigh Woolshed.

South Coast: Narrikup; brick pit 3 miles northeast of Albany; apparently also at Cape Riche and on the Bremer River. All in the Plantagenet series of lower Miocene age.

Comparisons.—*Aturia clarkei* differs from *Aturia australis* in the following respects: The shell of *A. clarkei* is proportionally broader, particularly the ventral side is more broadly rounded and the shallow impressed zone on the flanks is absent; the shape of the septa is quite different, particularly in the median longitudinal section which is evenly concave in *A. clarkei* and sickle-shaped in *A. australis*. The siphuncle in *A. clarkei* is probably somewhat larger proportionally; the sutures of the species differ from one another in that the lateral saddle in *A. clarkei* is asymmetrical and not evenly curved as in *A. australis* (text fig. 3); the lateral lobe is set more distinctly apart, and its ventral side rises higher than in *A. australis*.

The only other species with which *Aturia clarkei* needs to be compared is an unnamed *Aturia* from the upper Miocene of Java, described by Durham in 1940. Dr. Spath, who examined Durham's specimens, thought that they were comparable to *Aturia aturi*. The cross section figured by Durham is much broader than that of any Western Australian specimen, and the impressed zone is much narrower and shallower. The suture is more like that of *A. clarkei* in its asymmetrical lateral saddle, but the lateral lobe seems to be situated more in the middle of the flanks and the ventrolateral saddle

rises to the same height as the lateral saddle. On the available evidence I do not think that this Javanese specimen belongs to *A. clarkei*.

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TWO NEW AMMONOIDS FROM THE PERMIAN OF WESTERN AUSTRALIA

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ABSTRACT—The two new ammonoids are *Agathiceras applanatum* Teichert, n. sp., and *Pseudoschistoceras simile* Teichert, n. gen., n. sp. Notwithstanding many previous references this is the first authentic record of the occurrence of *Agathiceras* in Australia. The new genus *Pseudoschistoceras* may have been derived from *Schistoceras* Hyatt from which it differs by the possession of one additional pair of lobes.

NEW DATA regarding the Permian ammonoid fauna of Western Australia are accumulating slowly, and some finds which were made after my recent description of Permian ammonoids from this part of the world had been completed seem to merit a special description. The new finds were made in 1941 in the North-West Division of Western Australia in the same general area from which some of the ammonoids described in 1942 were derived (Teichert 1942, p. 221, map).

One specimen which represents a new species of *Agathiceras* was found by William Johnson on field work with the writer near Wandagee Hill. *Agathiceras* has often been reported from the "Permo-Carboniferous" of Australia, but all such references seem to be in error. The great majority of them refer to a species which was originally described as *Bellerophon micromphalus* by Morris in 1845. The species did not resemble typical bellerophontids as they were known at that time, and consequently it was referred to "*Goniatites*" by de Koninck in 1877. A few years later, however, Waagen (1880, p. 160) maintained that this Australian species was a bellerophontid and belonged to his newly established genus *Warthia* of which he had found representatives in the *Productus* limestone of the Salt Range of India. New evidence was introduced by Etheridge in 1894 when he described two specimens from the Permian of New South Wales which he believed to be conspecific and to which he applied the name *Goniatites* (*Prolecanites?*) *micromphalus*. One of these specimens showed some traces of a suture, the other one not. Some of the suture lines were figured by Etheridge (1894, pl. 7, fig. 12). It is this figure which led Foord and Crick in 1897 (p. 271) to place the species with reservation in the genus *Agathiceras*. This then remained its recognized position for a long time, and references to the occurrence in the "Permo-Carboniferous" of Australia of *Agathiceras micromphalum* (with or without a "?") are frequent in stratigraphical and palaeontological papers published in Australia and elsewhere. It was not until 1926 that Whitehouse resurrected the species as a member of the genus *Warthia* without, unfortunately, publishing any further remarks on the question. In 1929 (see Reid 1929, p. 80) Whitehouse recognized, after having studied specimens of alleged *Agathiceras micromphalum* and having regard to Etheridge's paper of 1894, that

> two similarly coiled species a common gastropod and a rare cephalopod, have been referred to this one species by earlier writers.

Thanks to the courtesy of H. O. Fletcher, of the Australian Museum, Sydney, I have since had the opportunity of studying Etheridge's original specimens, and I have thus been able to confirm Whitehouse's conclusions. The cephalopod, however, does not belong to the genus *Agathiceras;* it represents a new species of the much rarer genus *Adrianites*, which has been described in another paper by Fletcher and the present writer. With the exception of this unique specimen all other references to "*Agathiceras*" *micromphalum* seem to refer to members of the genus *Warthia*, and the genus *Agathiceras* should therefore be finally struck from the list of Permian fossils of New South Wales.

It is, therefore, of some interest that a

true representative of *Agathiceras* has at last been found in Australia. The new species *A. applanatum* is a typical member of that genus. It is closely related to *Agathiceras sundaicum* Haniel from Timor and thus constitutes another link between the Timor and West Australian faunas. In fact it is here suggested that some of the specimens which in the past have been determined as *A. sundaicum* might actually belong to the Western Australian species.

The second species discussed in the present paper represents a new genus for which the name *Pseudoschistoceras* is proposed, with *P. simile* as its genotype. The first specimens of this species were discovered early in 1941 by a station hand on Wandagee Station. They were handed to H. Coley, who in turn kindly forwarded them to me. From the appearance of the external suture I determined the specimens as a new species of *Schistoceras*, and was then, of course, very anxious to ascertain from which geological horizon the specimens had come, because it seemed that these ammonoids must be considerably older than any other late Palaeozoic ammonoid fauna found hitherto in Western Australia. Later in 1941 I was able to visit the country from which the first specimens had been obtained, and a map of the wider environments of the locality was prepared in collaboration with Professor E. de C. Clarke and two students of the University of Western Australia. Additional specimens were collected in which the internal suture could be studied, and it became evident that the new ammonoids belonged, not to *Schistoceras*, but to a new genus which is very closely similar to that genus.

The type locality of *Pseudoschistoceras simile* is situated approximately 20 miles south of the outcrop area around Wandagee Hill and on the Minilya River from which *Propinacoceras australe*, *Paragastrioceras wandageense*, and *Pseudogastrioceras goochi* were described in my previous paper (1942). Their stratigraphical position is, however, very much lower than that of those species. The specimens were found in limestone bands at the base of the Barrabiddy shale series, stratigraphically about 3,500 feet below the base of the Wandagee series and approximately 4,100 feet below the lowest ammonoid horizon in that series which contains *Propinacoceras australe*. Unfortunately, it cannot be said how the *Pseudoschistoceras* beds are situated in relation to the ammonoid-bearing horizons at the Irwin River and in the Kimberley District. The accompanying fauna gives no definitive clue, and deductions as regards the possible age of *Pseudoschistoceras* can only be made with great reservations. As will be explained below it may be possible to regard *Pseudoschistoceras* as a derivative of *Schistoceras*, from which it may have originated by the development of an additional pair of lobes, although the fact that *Schistoceras* has as yet not been found outside North America may speak against such an interpretation.

Schistoceras in North America is essentially an upper Pennsylvanian genus, although representatives seem to occur as rarities in early Permian (lower Wolfcamp) beds (Sellards 1933, p. 148; Plummer and Scott, 1937, p. 257, P. B. King, 1937, p. 95). If *Pseudoschistoceras* is derived from *Schistoceras* it should be younger than Carboniferous though not very high up in the Permian. A Sakmarian age or an age somewhere at the transition from the Sakamarian to the Artinskian would at present seem a possible suggestion.

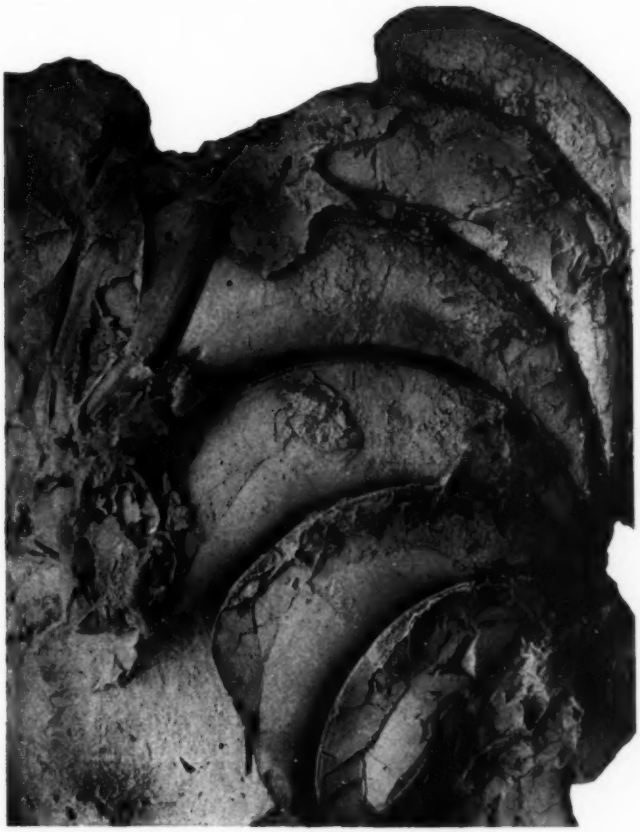
The Permian ammonoid fauna of Western Australia now comprises the following nine species:

Propinacoceras australe Teichert
Metalegoceras jacksoni Etheridge

EXPLANATION OF PLATE 16

FIGS. *1*, *2*—*Aturia clarkei* Teichert, n. sp. *1*, Miocene, Plantagenet beds, Narrikup, Western Australia, Mus. and Art Gallery, Perth, no. G 6033, ×1. *2*, Median section, ×1, from the type locality, Kennedy Range, North-West Division, Western Australia, Univ. Western Australia, Dept. Geology, no. 21407b. (p. 79)

3—*Aturia australis* McCoy. Median section, ×2; Miocene, Muddy Creek, Victoria; F. A. Singleton's collection, Melbourne. (p. 76)



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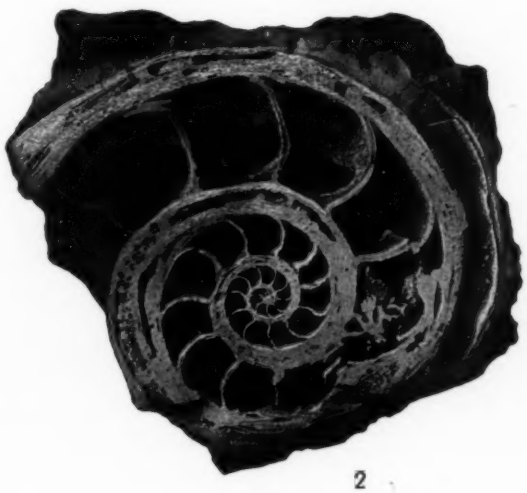

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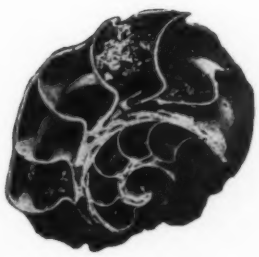

3

Teichert, Aturias from Australia

Teichert, Permian Ammonoids from Australia

Metalegoceras clarkei Miller
Metalegoceras striatum Teichert
Paragastrioceras wandageense Teichert
Pseudogastrioceras goochi Teichert[1]
Pseudoschistoceras simile Teichert, n.sp.
Thalassoceras wadei Miller
Agathiceras applanatum Teichert, n.sp.

PALAEONTOLOGICAL DESCRIPTIONS

Genus AGATHICERAS Gemmellaro, 1888

The genus *Agathiceras* and its position within the family Agathiceratidae and the relations of the members of that family with those of the Adrianitidae, which they resemble very closely, has in recent years been thoroughly discussed by Schindewolf (1931, p. 199), Böhmers (1936, p. 65), Miller and Furnish (1939), and Ruzhencev (1939, 1940a). *Agathiceras* comprises mostly broadly discoidal to subglobular shells, mostly with longitudinal lirae on the surface; its sutures consist of 12 lobes and 12 saddles which are tongue or V-shaped; the elements of the external sutures are all of fairly equal size. The external suture is devided by a large median saddle into two prongs which are large and straight. Representatives of the genus are found widespread in North America, in Europe, and in the East Indies in rocks which range from the Lower Carboniferous to the Middle Permian (see Miller and Furnish, 1940a, p. 119).

Ruzhencev has pointed out (1938, p. 263) that representatives of the genus *Agathiceras* changed but slightly in time and that "their determination consequently involves great difficulties and is based, mainly, on measurements on the conch." It is quite possible that the Western Australian species described below will be found to fall within the extreme range of one or two previously described species, such as *Agathiceras uralicum* Karpinsky or *Agathiceras sundaicum* Haniel. Apparently, a very much larger number of specimens is required to establish the exact relationships between the various species of this genus.

[1] If the systematic arrangement of the *Gastrioceratidae* as proposed by Ruzhencev in 1936 is adopted, *Pseudogastrioceras goochi* should be referred to the genus *Uraloceras* Ruzhencev (1936, p. 1087), which has *Gastrioceras suessi* Karpinsky as its genotype. This genus is supposed to differ from typical *Pseudogastrioceras* in its discoidal form and in the great width of the prongs of the ventral lobe. Miller and Furnish (1940) thought that these differences were hardly of generic rank and they, therefore, dropped *Uraloceras* as a synonym of *Pseudogastrioceras*. This view was contested by Ruzhencev (1940b, p. 286), although he admitted that *Uraloceras* was very close to *Pseudogastrioceras*. One will undoubtedly have to agree with Ruzhencev (1940b, p. 288) if he says that palaeontology now has reached a stage "when classification of fossil organism cannot possibly be grounded on the opinion of this or that author," but that such a classification must be based on ontogenetical and phylogenetical studies. However, until the differences between *Uraloceras* and *Pseudogastrioceras* have been worked out in more detail on the basis of such investigations, one may still accept the genus *Pseudogastrioceras* in the wider sense which it was given by Miller and Furnish.

AGATHICERAS APPLANATUM Teichert, n. sp.

Plate 17, figures 6, 7; text figure 1

The holotype is a specimen with a somewhat weathered surface and a damaged living chamber, but is otherwise well preserved. The shell is narrowly discoidal, strongly involute, with moderately convex flanks, which converge ventrally, and a narrowly curved venter. Its dimensions are: greatest diameter, 18.8 mm.; height of last whorl, 11 mm. (approx.); height of penultimate whorl, 6.2 mm.; height of last whorl above venter, 7.2 mm.; thickness at base of living chamber, 8.5 mm.; width of umbili-

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EXPLANATION OF PLATE 17

FIGS. *1–5*—*Pseudoschistoceras simile* Teichert, n. sp. Base of Barrabiddy shale series, Permian, ¼–½ mile S. of Barrabiddy Dam, Wandagee Station, North-West Division, Western Australia. *1*, *2*, Paratype 21329; *3*, paratype 21327; *4*, holotype 21326; *5*, paratype 21440, ×1. (p. 88)

6, *7*—*Agathiceras applanatum* Teichert, n. sp. Near top of Wandagee series, Permian. East side of Wandagee Hill, Wandagee Station, North-West Division, Western Australia. Holotype 21451, ×2. All specimens in the Dept. of Geology, University of Western Australia. (p. 85)

cus, 1.5 mm. The ratio of width of shell to diameter is about 0.45. Of the living chamber there is only a fraction 14 mm. long preserved, equalling about one-fourth of a volution. It is probable that the shell would appear to be broader if the entire living chamber were preserved.

The surface of the shell is covered with regular, evenly spaced, uniform, slightly raised lirae which, on the living chamber are 0.5 mm. apart. No other ornamentation is apparent.

The external suture (text fig. 1) consists of the external lobe, which is divided by a median saddle, and of three lateral lobes and four lateral saddles. The median saddle is about three-fourths the length of the external lobe; it divides the latter into two halves, each of which is somewhat larger than the adjacent first lateral lobe. The internal suture could not be studied.

Occurrence.—Upper part of *Linoproductus* stage of Wandagee series, 300 yards east of mouth of southeastern gully of Wandagee Hill, Mungadan Paddock, Wandagee Station, North-West Division, Western Australia, where it is associated with *Pseudogastrioceras goochi* (see Teichert 1942, p 228). The only known specimen is the holotype, no. 21451, Department of Geology, University of Western Australia.

Remarks.—The genus *Agathiceras* has few

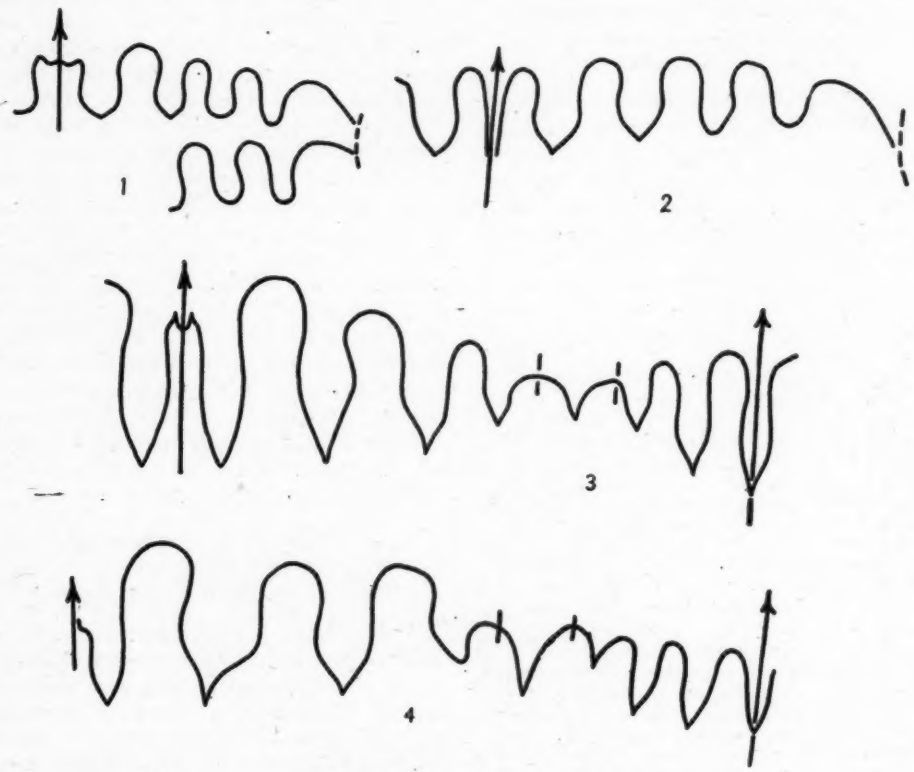

FIG. *1*—*Agathiceras applanatum* Teichert, n. sp. External suture of holotype, ×4. (p. 85)
2—*Agathiceras sundaicum* Haniel. External suture of a specimen from the Bitauni beds, Timor, possibly identical with *A. applanatum*, about ×5. Adapted from Haniel, 1915, pl. 49, fig. 13c. (p. 87)
3—*Schistoceras missouriense* (Miller and Faber). Complete suture, ×1.7. Adapted from Miller and Furnish, 1940b, p. 523, fig. 1d. (p. 88)
4—*Pseudoschistoceras simile* Teichert, n. sp. External suture of holotype, ×1.8. (p. 88)

external features that serve to distinguish it from members of the family Adrianitidae, which belongs to an entirely different division of Palaeozoic ammonoids as shown by Schindewolf and Böhmers. Miller and Furnish (1939), however, have stated that in the Agathiceratidae the two prongs of the external lobe are always large and straight, whereas in the Adrianitidae they are short and curved. The external lobe of *Agathiceras applanatum* is of the former type, and one may therefore feel reasonably sure that we are concerned with a true *Agathiceras* even though the development of the suture and the position of the siphuncle in the early stages have not been studied.

Agathiceras sundaicum Haniel (1915, p. 66) from the Permian of Timor is rather similar to our species. Haniel described the shape of the conch of *A. sundaicum* as very variable and says that gradations connect that species with *A. suessi*, *A. uralicum*, and *A. ciscoense*. Typical specimens of *A. sundaicum* seem to be rather thicker than *A. applanatum*. From the measurements given by Haniel (1915, p. 66) it can be calculated that a normal specimen of *A. sundaicum* with the same diameter as that of the holotype of *A. applanatum* has a ratio of width to diameter of about 0.6.

However, Haniel (1915, pl. 4, fig. 13) has figured one specimen which he described as "sehr schmal" and which has approximately the size and proportions of *A. applanatum*. Measurements taken from Haniel's figures suggest that the ratio of width to diameter in this specimen must have been about 0.45, that is the same as in the holotype of *A. applanatum*. This specimen also has a suture (text fig. 2) which differs slightly from that of other specimens of *A. sundaicum*. While that species generally seems to be characterized by somewhat narrow and comparatively long saddles and lobes, as is also evident from the illustrations published by Smith (1927, pl. 9), the small specimen figured by Haniel has a suture more similar to that of the holotype of *A. applanatum*. More particularly it is also characterized by the stronger development of its external lobe. Also the flanks of the shell converge towards the venter, whereas those of typical *A. sundaicum* tend to be parallel. I think, therefore that this Timor specimen should be referred to *A. applanatum*. Haniel states that it was found between Soefa and Manoema and that it was associated with *Propinacoceras simile* and with *Popanoceras tridens*. The former species is closely related to *Propinacoceras australe* from the Wandagee series of Western Australia.

A. applanatum is also very similar to *A. uralicum* from the Sakmarian of the Urals (Karpinsky 1889, p. 103; Ruzhencev 1938, p. 263). This is a rather slender species, but the ratio of width to diameter of specimens of approximately the same size as the holotype of *A. applanatum* is about 0.55 as against 0.45 in the latter. Also the two prongs of the external lobe are hardly as large as in *A. applanatum*. There are also certain resemblances to such Texas species as the upper Pennsylvanian *A. ciscoense* Smith and the lower Permian *A. applini* Plummer and Scott, which both include fairly narrow specimens with a large external lobe. Also *A. asselicum* Ruzhencev (1938, p. 263) from the Sakmarian of the Urals is a comparable species.

On the whole it seems that *A. applanatum* resembles earlier rather than later species of the genus, which is remarkable in view of the fact that the stratigraphical occurrence of the Western Australian species must be well up in the Artinskian.

Genus PSEUDOSCHISTOCERAS Teichert, n. gen.

This genus is here established to include shells which are externally similar to *Schistoceras* but differ from that genus in having an additional pair of lobes just inside the umbilical seam. The external suture is identical with that of *Schistoceras*. The new genus has a total of 16 lobes and 16 saddles, all of which are simple, in addition to the odd median saddle which divides the ventral lobe.

Genotype, *Pseudoschistoceras simile* Teichert, n. sp.

Owing to the nature of the material in which the specimens of the genotype are preserved, it has been impossible to study the ontogenetical development of the sutures of the species. All that can be said is that the mature suture is very similar to that of *Schistoceras*, from which it differs in

the presence of one additional pair of lobes. The smallest of all the lobes is the pair just inside the umbilical seam, and it appears, therefore, that this might be the one which has been formed last. The resemblance between the external suture of *Pseudoschistoceras simile* and that of a true *Schistoceras* is very remarkable as shown by a comparison with *Schistoceras missouriense* (text fig. 3).

It is proposed tentatively to include *Pseudoschistoceras* in the Schistoceratidae and to regard it as the terminal member of the *Pseudoparalegoceras-Diaboloceras-Paralegoceras-Schistoceras* lineage, which has recently been the subject of a study by Miller and Furnish (1940b).

Plummer and Scott (1937) have described two genera under the names of *Paraschistoceras* and *Metaschistoceras*. The former was said to differ from *Schistoceras*—among other features—by "a notched umbilical lobe" and the latter by having two extra lobes and saddles on the umbilical shoulder and wall. Miller and Furnish (1940b, p. 538) regarded both these names as synonyms of *Schistoceras*. However, regardless of any discussion that might arise with respect to the validity or otherwise of *Paraschistoceras* and *Metaschistoceras*, it will be seen that the extra pair of lobes which distinguishes *Pseudoschistoceras* from *Schistoceras* is situated at a different place, viz., inside the umbilical seam, forming part of the internal suture, and that these lobes are much more completely developed and therefore of a different order from those in either of Plummer and Scott's genera.

PSEUDOSCHISTOCERAS SIMILE
Teichert, n. sp.
Plate 17, figures 1–5; text figure 4

Shell discoidal, moderately involute, with the width of the umbilicus equalling almost one half of the diameter of the conch. The ventral outline of the whorls is strongly convex, the dorsal outline more evenly concave. Every whorl is indented to about one-half of its height by the preceding whorl. At the umbilical shoulder the shell is bent almost at a right angle. The umbilical wall is narrow and even, in the largest specimen not more than 4 to 5 mm. wide.

Measurements of four more or less complete specimens are as follows (in mm.):

	Holotype 21326	21327	21328	21329
Diameter	76.0	72.5	61.5	53.5
Height of last whorl	29.0	23.3	18.5+	20.0
Height of last whorl above venter	15.0	12.0	?	10.0
Thickness	22.0	17.8	?	12.5
Width of umbilicus	35+	32.0	28+	26.0
Length of preserved portion of living chamber (in volutions)	¼	1	0	9/10
Ratio of width to diameter	0.48	0.44	0.45	0.48

Among the less complete specimens there is one fragment of a whorl 44 mm. high. The original diameter of that specimen is estimated to have been about 100 mm.

All the specimens are internal moulds whose surface is smooth. Nothing can be said about the outer shell features of the species.

The suture (text fig. 4) consists of 16 saddles and 16 lobes, the ventral one of which is divided by a median saddle, which is about one-half the length of the first lateral saddle.

The external suture resembles very closely that of *Schistoceras missouriense* (text fig. 3). The two prongs of the ventral lobe are rather narrow and straight; they are as a rule not wider than about one-half the width of the first lateral lobe. The first lateral saddle is broadly and evenly rounded; the first lateral lobe is fairly broad, somewhat bulbous, and drawn out into a fine point. The second lateral saddle is only slightly smaller than the first saddle, but the second lateral lobe is somewhat narrower than the first lateral lobe. The third lateral saddle is still broadly rounded, but the third lateral lobe is very much shorter than the other and is unsymmetrical, with a sudden bend in its external flank. The next saddle is the external umbilical saddle, which is halved by

the umbilical shoulder. It is very low. The next lobe lies between the umbilical shoulder and the umbilical seam on the umbilical wall and is rather short and pointed. The next following saddle is halved by the umbilical seam; it is of approximately the same size and shape as the saddle on the umbilical shoulder. The internal suture consists of seven lobes and six saddles. The pair of lobes next to the umbilical seam is short and pointed. This is the shortest pair among all the lobes. It is followed inwards by two approximately equal lobes on each side of the dorsal lobe. Compared with the first two external lobes, these lobes are much narrower and taper more gradually. They are separated from one another and from the adjacent lobes by rather narrow saddles. The internal dorsal lobe is likewise narrow though slightly longer than the adjacent lobes.

Occurrence.—Weathered out of calcareous mudstone bands on mud flat ¼ to ½ mile south of Barrabiddy Dam, Wandagee Station, North-West Division. From strata close to the base of the Barrabiddy shale series. Holotype no. 21326; paratypes, nos. 21327, 21328, 21329, 21330a, b, Department of Geology, University of Western Australia.

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A PERMIAN SHARK FROM THE GRAND CANYON

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ABSTRACT—A dental armature, evidently of a petalodont shark, from the Permian of the Grand Canyon, Arizona, is much larger than that of any known related form. The new type, *Megactenopetalus kaibabanus*, sheds light on the development of a group of sharks known only by single teeth, and which died out at the end of the Paleozoic.

A FRAGMENT of an unusually large selachian dentition was collected by Kenneth Allen of Salt Lake City, on the North Rim of the Grand Canyon. The specimen is of particular interest not only because of its geologic occurrence but also because it is eight or more times as large as the dentitions found in the most nearly related forms. The fossil was given to L. F. Brady of the Museum of Northern Arizona, who very kindly sent it to Dr. Chester Stock of the California Institute of Technology for identification. I am grateful for the opportunity to study this interesting shark.

The specimen was found on the surface of the ground near Point Sublime on the North Rim of the Canyon. The horizon whence the dentition comes is near the top of the "beta" member of the Kaibab formation and is of middle Permian age. The facies at this locality corresponds to facies 3 of McKee (1938). It is approximately the same facies as that which occurs near Desert View on the South Rim. Remains of fish appear to be relatively rare in the Kaibab formation. The fine-grained sandstone of the beta member has yielded a tooth of *Deltodus mercurii* Newberry. This form ranges from the Carboniferous on upward and has its latest known geologic occurrence at the Grand Canyon locality. In addition, a tooth of *Janassa*, a genus known chiefly from the lower Permian, and several teeth that probably belong to *Mesodus*, have been found.

Subclass BRADYODONTI
Family PETALODONTIDAE
MEGACTENOPETALUS KAIBABANUS
David, n. gen., n. sp.
Plate 18, figures 1, 2

Type.—No. G. 2.2280 in the file of the Museum of Northern Arizona. Greatest height of preserved portion, 90 mm.; greatest length, 96 mm.; greatest width of crown, 12 mm.; greatest width of root, 26 mm.

Type locality.—Near Point Sublime on North Rim of Grand Canyon, Arizona.

Description.—The type and only specimen is a fragment of a dental armature probably of the upper jaw of the shark. Almost the entire left half with the middle symphyseal area is preserved. Nearly all of the right side of the fossil is lost. The extreme end of the left side of the dentition and the basal portion of its root are also missing. Anterior and posterior views of the fossil are shown in plate 18, figure 1. Since the exterior and interior sides of the fossil are preserved beyond the middle line, a reconstruction of the missing half of an evidently bilaterally symmetrical dentition seems to be reasonably well founded (pl. 18, fig. 2).

The fossil shows in general the petaloid shape of tooth. The crown in its deepest central portion is 55.25 mm. high. The root is preserved to a depth of 36 mm. The tooth is curved laterally; when complete it evidently formed a semicircle with a diameter measuring 116 mm. The tooth portion of the crown consists of a relatively dense grayish brown dentine. The crown is continuous with the root and passes into the coarse spongy mass which comprises its bony support. The rusty-brown spongy bone is covered by a layer of the dark-gray dense dentine, which is 2 or 3 mm. in thickness. A very thin whitish layer is spread over the outside of the fossil and appears to be comparable to an enamel covering.

The toothed portion of the crown is preserved on the left half only. The individual teeth are fused with each other and are continuous with the base of the crown. Five teeth are present, but the top of the fifth

one is broken. Possibly a sixth tooth was present, but since the vertical depth of the crown of the fifth tooth is quite low this appears doubtful. The height of the crown decreases rapidly toward the outer extremity of the dentition, while the decrease in length of teeth is less marked. The teeth overlap each other, so that the inner border of each tooth protrudes beyond the anterior face of the higher tooth next to it. The highest and most central tooth is complete and is rounded toward the interior face. It evidently was overlapped on its outer side by the tooth next following. A deep groove marks the interspace between the teeth, and this groove may be continued as a thin wavy line for some distance on the basal undivided portion of the crown. The teeth are almost flat on the posterior face and distinctly convex on the anterior face, thinning out toward their rims. The distal borders of the teeth form sharp cutting edges and show no serrations. The posterior faces of the teeth are marked by very fine radiating lines on their upper edges. There are about 28 on the central tooth, 26 on the second, and 24 or less on the more lateral ones. The crown is deepest immediately to the left of the median notch and measures here 54 mm. The complete row of teeth was apparently 93 mm. long. Measurements of four individual teeth are as follows: depth, 24, 20, 14, and 11.5 mm.; length, 24, 24, 21, and 15 mm.; depth along dividing groove between first and second, 11.5 mm.; second and third, 9.2 mm.; third and fourth, 4.5 mm.

The base of the crown is marked on the anterior side by a pronounced fold forming a trenchant edge protruding for about 7 mm. beyond the vertical face of the root. The fold is notched on the vertical face below the outer border of the highest preserved tooth. A median incision divides the notch into two symmetrical portions. This evidently marks the middle of the dentition and may be comparable to the symphysis of the jaw. Beginning at the notch the fold gradually curves upward for a distance of 19 mm., at which point is it marked by an indentation. Beyond this the fold is almost level, only very slightly curving upward to another indentation below the outer border of the fourth tooth, where the line of the fold curves downward again. On the right side of the fossil this structure is preserved for only a short distance beyond the first indenturation.

On the posterior side the dentition is strengthened by a very deep, strong welt. This welt extends upward and laterally from a deep pit on the median line of the posterior face of the coronal cavity. The greatly curved upper border of this welt protrudes beyond a shallow groove at its middle portion. Its highest point lies below the interspaces between the second and third tooth (counting laterally from the median line). At this point the vertical section of the welt is 38 mm. deep. A median, slightly curved ridge 6 mm. thick further strengthens the welt. The upper border of the ridge lies 16 mm. below the highest point of the welt, its lower border 29 mm. above the lower margin. A similar thickening must have been present on the missing right portion of the fossil, as is indicated by the preserved basal part, which rises upward from and lateral to the median pit. The extreme end of the median ridge is also present. The vertical section of the root wall plus the welt is thickest along the axis of the median pit, and here measures 26 mm. Welt and root wall thin out towards the outer extremity of the dentition and are 17.3 mm. thick at the thinnest preserved portion.

CORRELATION OF MORPHOLOGY AND AGE

The shape of the jaw and dentition in *Megactenopetalus* resembles closely that seen in various genera of petalodontoid sharks from the Permo-Carboniferous, except for its huge size.[1] Certain minor differences in its structure may be accounted for by the extraordinary size. All genera showing teeth with outlines more or less similar to those in *Megactenopetalus* have now been assigned to the family Petalodontidae. The nearest related species, described under various generic names as *Ctenopetalus* Davis, *Harpacodus* Davis, *Peripristis* St. John and Worth, are now known under the name *Ctenopetalus*. *Megactenopetalus* resembles

[1] Dr. William K. Gregory and Miles Conrad kindly compared sketches of the fossil from the Grand Canyon with specimens in the Newberry collection of the American Museum of Natural History.

closely *Ctenopetalus* (*Peripristis*) *semicircularis* (Newberry and Worthen, 1866, p. 72, pl. 6, figs. 18, a, b; Eastman, 1902, text figs.). The latter shows also the much compressed, laterally curved crown, which forms almost a semicircle; a basal ridge is present on the anterior side; and a "broad shoulder, depressed at the center with a deep conical cavity" is present on the posterior face at the junction of crown and root. The deep notch of the basal ridge is not always present in *Ctenopetalus semicircularis* and is never so pronounced as in *Megactenopetalus*, but it is described in *C. falcatus* and in other species. The symphysislike division of the fold is clearly seen only in the large Permian fossil. Also, the shoulder or welt is more highly developed and shows special features in the Permian form, as for example, its strengthening by a median ridge and its deep gracefully curved upper portion. The toothed portion in *Megactenopetalus* comes nearest to *C. semicircularis* among all the Carboniferous types. The preserved part shows at least five denticles or lobes. *C. semicircularis* is said to have four on one side, five on the other. Since the symphyseal division in *Megactenopetalus* lies almost on a line with the median border of the middle tooth, it seems likely that a corresponding tooth of the same or similar size occurred on the lost right half of the jaw. In the reconstruction, therefore, five teeth are indicated on the right side, corresponding to those of the preserved part. The lobes or teeth in the large Permian fossil are much more like actual teeth than the lobelike protuberances in the smaller Carboniferous forms. In the latter the number and shape of the lobes are variable.

Not much is known of the shape and size of the sharks of this group. None of the teeth of the nearly related forms has been found in place in the jaw. All of them have been collected as detached and single teeth. It is believed, however, that the teeth of upper and lower jaws were different in these forms. *C.* (*Peripristis*) *semicircularis* shows a smaller number of denticles in the lower jaw than in the upper (Eastman 1902). The related genus *Peristodus* Davis has a lower dentition with straight edge, whereas 10 to 18 denticles are present in the upper jaw of *P. falcatus*. In the latter the upper tooth bites directly outside the opposing tooth, and its posterior face is so shaped as to fit precisely to the crown of the tooth of the lower jaw. Woodward (1889) concludes:

> These characters are suggestive of there having been but a single tooth in each jaw of the original fish.

Eastman (1902) substantiates this fact. No find has been made since then to prove this suggestion definitively.

The entire structure and the size of *Megactenopetalus* are highly in favor of such a condition. The tooth of *P. falcatus* (as in all other known forms) is considerably smaller than in *Megactenopetalus*, for its crown is no more than 7 mm. high and no wider than 15 mm. The *Pristodus* tooth is approximately one-eighth as large as the Permian form. It is not readily conceivable that very many teeth of the size and shape of those in *Megactenopetalus* formed part of one jaw. It is much more likely, as stated above, that only a single tooth was present in each jaw. The structure and outline of the Permian dentition also is rather that of a jaw than of a single tooth, as indicated by the strong root portion with its protruding ridge on the anterior face and the gumlike welt on the posterior face. The laterally bent dentition is almost semicircular, having thus the shape of a normal complete jaw. The fossil is likely to represent part of the upper jaw biting outside the opposite tooth that fitted with its apex into the median pit. The broad inside welt might then represent part of the roof of the mouth. The symmetrically divided median notch of the anterior face probably corresponds to the median symphysis of the jaw.

The difference in size between the new form and those known previously is important. It would be interesting to know if the same difference in size existed between the animals themselves. This would probably imply that *Pristodus* and some of the other Carboniferous forms were quite small compared with other known sharks. On the other hand, it is possible that the jaws of the earlier forms of the group were equipped with a number of teeth, and that the trend of development was towards a decrease in number of teeth with strengthening and enlarging of the one or few remaining ones. In this case the difference in size between the

Megactenopetalus kaibabanus David, n. gen., n. sp.

Dental armature no. G. 2.2280, Museum of Northern Arizona, from the Permian near Point Sublime, Grand Canyon, Arizona. *1a*, Anterior face; *1b*, posterior face; x 3/5. *2*, Plaster cast of dentition with opposite right side restored; oral view from below, x ¾.

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earlier and later fishes would not have been so remarkable. The dental armature of *Megactenopetalus*, even if represented by only a single pair of opposing teeth, was undoubtedly one of a powerful fish constructed for cutting and lacerating its prey.

The majority of related forms are present in the Carboniferous of Europe and North America. *Pristodus* and *Ctenopetalus* are known from the Lower and Upper Carboniferous of England, Scotland and Ireland. *Ctenopetalus* is found also at numerous localities in North America—in the Mississippian (Chester) of Iowa, Illinois, Ohio and Indiana; in the Pennsylvanian (Missourian) of Iowa, Nebraska, and West Virginia. It is occasionally found in the Permian of Kentucky, Kansas, and Iowa. As a rule shark's teeth are encountered more often in the Carboniferous than in the Permian. Carboniferous sharks are better known and new discoveries are more apt to be made in the uppermost stages of the Paleozoic. The Petalodontidae were widely distributed in the Carboniferous seas. It can be postulated that their greatest development occurred in Upper Carboniferous time when they gave rise to the larger specialized forms (*Janassa*, *Megactenopetalus*) in the lower Permian. Their extinction occurred at the end of the Paleozoic.

The Permian shark *Megactenopetalus* occurs in facies 3 of the beta member of the Kaibab formation. This facies represents a near-shore deposit in a region where streams were supplying abundant clastic sediments, and where the environment was probably brackish or relatively fresh. This kind of environment is known to be the habitat of most recent and many extinct sharks.

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HYSTATOCERATIDAE OR DIPOLOCERATIDAE?

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ABSTRACT—An attempt is made to prove that the replacement, recently suggested by Spath, of the family name Dipoloceratidae by Hystatoceratidae is unnecessary.

VOLUME 96 of the Palaeontographical Society, London, containing Part 15 of Dr. L. F. Spath's "Monograph of the Ammonoidea of the Gault" (Spath, 1942), became available to the writer only after his paper on Albian ammonites from Angola (Haas, 1942) was already in page proof. Thus it was impossible to refer in that report to Spath's latest opinions on some of the subjects involved.

In the present article a single taxonomic problem raised by Spath's last publication, as indicated in the title, is discussed: After having established the family Dipoloceratidae in 1921 (Spath, 1921, p. 277; 1922, pp. 107, 113) and later, though doubtfully (1934, pp. 443, 465), split off the Mortoniceratidae (1932, p. 379, not 1925, p. 199), called previously "Inflaticeratidae" (1925, p. 199), then Pervinqueridae (1931, p. 346), and the Brancoceratidae (1934, p. 465), Spath now (1942, p. 705) returns to his first conception, "accepting Mortoniceratinae as a subfamily of Dipoloceratidae." However, he adds:

> Only since the latter family dates from 1921 . . . , whereas the family Hystatoceratidae was created by Hyatt already in 1900, the larger unit, if adopted, would have to be Hystatoceratidae (="Brancoceratidae") and Dipoloceratinae would become one of the subdivisions of that family.

The reader will have noted the hypothetical form of this sentence; still another fact appears to prove that Dr. Spath made this proposal not quite wholeheartedly. Despite his above conclusions he chooses, as heading for Chapter 8 of his "Palaeontological and stratigraphical results," not the family name "Hystatoceratidae," but rather the paraphrase "The keeled ammonites of the Gault," agreeing almost verbally with the title given by van Hoepen to his paper of 1941.[1] However, the typical forms of *Brancoceras*, *Hystatoceras*, and *Hysteroceras*, and also some *Neokentroceras*, all of which genera are now included in this group by Spath, are unkeeled in maturity.

In my opinion there is no need for the change conditionally proposed by Dr. Spath. First of all, it may be considered common opinion (see, e.g., Schenk and McMasters, 1936, p. 5) that "priority, at present, is not generally regarded in the disposition of family names," the law of priority applying to generic and specific names only (Arts. 25–31 of the Rules of Zoological Nomenclature). But even if it would apply to family names as well, this would not alter the present case, since Hyatt (1900, p. 590) when creating his family Hystatoceratidae, did not include his genus *Dipoloceras* which he referred to the Peroniceratidae instead (Hyatt, 1900, p. 589). So even under the above assumption Spath was free in 1921 to establish a new family Dipoloceratidae. As its type genus (Art. 4 of the Rules) was selected from Hyatt's family Peroniceratidae, he was equally free later to include in his family *Hysteroceras* (1925, p. 107) and *Hystatoceras*, thought by him at that time to be a synonym of *Brancoceras* (1931, p. 346), all three of which had originally been referred by Hyatt to the Hystatoceratidae; provided that Spath considered, as he still seems to do, *Dipoloceras* to be qualified for the type genus of this whole group.

[1] I, also, felt some embarrassment as to the selection of a sufficiently comprehensive name for this whole group of ammonites; they were, therefore, first (Haas, 1941) named "The sculptured, normally coiled ammonites," until I eventually made up my mind to include all of them in the Dipoloceratidae (*sensu lato*).

Dipoloceratidae as restricted by Spath (1921, p. 277; 1934, pp. 443–465), Roman (1938, pp. 367–377), and Haas (1942, p. 11) thus is a valid family, which might be subdivided into three subfamilies—Dipoloceratinae, Pervinquerinae, and Hystatoceratinae. The precise delimitation of these three subfamilies from each other does not fall within the scope of this article, nor does the question as to whether or not to keep *Hystatoceras* apart from *Brancoceras*, recently decided in the affirmative by Spath (1942, p. 710), and, in consequence, whether to call the third subfamily Hystatoceratinae or Brancoceratinae.

The second, however, ought, in my opinion, to be called Pervinquerinae rather than Mortoniceratinae, as proposed by Spath (1942, p. 705), who still regards *Mortoniceras* Meek as a potentially valid Albian genus. Spath has "every confidence that our American colleagues will be able to redescribe *A. vespertinus*, the type specimen of which is in existence," and thus hopes that some definite meaning will still be given to "*Mortoniceras*," which, for the time being, must be considered at least a *nomen dubium*. I can, however, not share Spath's optimism, since Adkins, on whom he chiefly relies, has not published any results referring to this problem for many years, whereas Stanton pointed out as late as 1937 that that type specimen is "a poorly preserved large fragment of an adult whorl" whose "specific identity will probably never be satisfactorily established." *Pervinquieria* should, therefore, definitely replace *Mortoniceras* as a generic name, as suggested by Roman (1938, pp. 376, 461), Breistroffer (1940, p. 72)[2] and myself (1942, p. 67).[3]

[2] This reference is made *fide* Spath (1942, p. 705), Breistroffer's paper not being available in U.S.A. (cf. Haas, 1942, p. 219, footnote 1).

[3] Quite recently Muller and Schenck (1943, p. 271, footnote 3) rejected "this nomenclatural change as it is not in accordance with international rules of zoological nomenclature, for reasons which will have to be explained in another paper." Discussion thus has to be postponed until the appearance of the announced paper.

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IMPRESSION OF A WORM ON THE TEST OF A CAMBRIAN TRILOBITE

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SEVERAL years ago Dr. Leif Størmer (1931) discussed the evidences that have been found that various plants and animals bored into the tests of living trilobites. He described the borings of what he believed to have been algae which he had found in trilobite tests from the Ordovician of Norway, and called attention to the fact that Portlock (1843, p. 360, pl. 21, fig. 5a) had published a description of what appeared to be worm borings in the tests of trilobites from Ireland. Peach (1894, pl. 32, fig. 15) has also figured what appears to be a worm boring in the cheek spine of an *Olenellus* from Scotland.

The writers have had occasion to examine a peculiar structure which may possibly be a worm boring in a trilobite test, but which seems to them to be more probably the impression of the body of a worm that has indented the test of a Lower Cambrian trilobite. This impression is so unusual, and the remains of Cambrian worms are so rare, that it seems desirable to call attention to this fossil, whatever may be its exact nature.

The fossil occurs as a furrow in the test of the cheek of an adult example of *Olenellus getzi* Dunbar, from the Lower Cambrian Kinzers formation, found at the famous Getz quarry, one mile north of Rohrerstown, Lancaster County, Pennsylvania, and is preserved in the paleontological collection of Princeton University (cat. no. 42083). Its general form can be seen in the figures here presented.

As the edges of the fossil are uneven and there is no direct evidence that the organism which produced it actually bored into the test of the trilobite, it seems probable that the indentation was made in the test by the body of a worm which was pressed down into the yielding surface of the trilobite. The shape of the fossil is such that it could hardly have been any kind of animal except a worm. It would seem that the worm had an unusually stiff body and that the test of the trilobite was relatively soft. The test of *Olenellus* was very thin and would probably yield easily to pressure (Raw, 1937, pp. 577–578).

There is no evidence to indicate that the worm had a shell of any kind, but there are traces of what look like segmentation of the body of the animal. These are not very distinct, for the indentation was filled at one time with limonite, some of which still remains, so that the internal details are not well preserved.

Worms are known to have been abundant in Early Cambrian seas, though their remains are seldom found preserved as fossils. The structure here described may be the impression of the body of one of the worms common in the Kinzers sea which has been preserved to us because of peculiarly favorable conditions of preservation. Such a worm may belong to an undescribed species and genus. Our specimen is too poorly preserved to justify our giving it a name, but it is hoped that some future student may be fortunate enough to find a better preserved example which will add to our knowledge of the animal, and permit of its naming and more accurate classification.

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1

2

Ruedemann and Howell, Cambrian Worm

Impression of worm (?) on right cheek of *Olenellus getzi* Dunbar. *1*, Cephalon of the trilobite, X 1; *2*, the impression, X 5.

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JOURNAL OF PALEONTOLOGY, VOL. 18, NO. 1, PP. 97–99, 1 TEXT FIG., JANUARY 1944

LAMELLINUCULA, A NEW SUBGENUS OF NUCULID PELECYPODS

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ABSTRACT—*Lamellinucula* Schenck, new subgenus, is typified by *Nucula tamatavica* Odhner, 1943. Strong concentric sculpture and crenulate inner ventral margin are among the distinctive morphologic features. The known range of the subgenus is Eocene-Recent, marine, cosmopolitan.

As the completion of my illustrated catalogue of some nuculid pelecypods is postponed indefinitely, I am recording here a new subgenus of *Nucula* in advance of the monograph.

Class PELECYPODA
Subclass PRIONODESMACEA
Order PROTOBRANCHIA
Family NUCULIDAE d'Orbigny, 1944
Subfamily NUCULINAE
Stoliczka, 1871
Genus NUCULA Lamarck, 1799
Subgenus LAMELLINUCULA
Schenck, n. subg.

Type of subgenus, by original designation, *Nucula tamatavica* Odhner (1943, p. 206), new name for *Nucula rugosa* Odhner (1919, pp. 23–24, pl. 2, figs. 15–18); Recent, Madagascar.

The subgenus is proposed for nuculid pelecypods ranging in length up to about 25.0 mm.; shell closed, not gaping; dorsal margin straight to gently arched; anterior extremity bluntly rounded (see fig. 1); ventral margin convex; posterior margin straight to convex; lunule and escutcheon indistinct to moderately well defined; beaks inturned, opisthogyrate; interior nacreous; taxodont dentition consisting of about 12 to 26 teeth in the anterior (long) series, 4 to 12 in the posterior (short) row; chondrophore distinct, sometimes heavy; two subequal adductor muscle scars and accessory scars as in other members of the family; pallial line entire; inner ventral margin denticulate (crenulate, crenate); incised, lamellate concentric sculpture more conspicuous than radial ribs or striae; from two to eight concentric ribs per millimeter.

Harold Heath (personal communication, June, 1943) has compared the soft parts of *Nucula tamatavica* with those of *Nucula nucleus* (Linnaeus), the type of *Nucula, sensu stricto*. He found differences in the number of palp grooves and in the shape and relative size of the palp appendage or tentacle, but these might be due to the preservative. Normally, the byssus of *N. tamatavica* is feebly developed, whereas it is a conspicuous organ in *Nucula nucleus*, *N. tenuis*, and *N. proxima*. The nervous and urogenital systems are similar in all species of the genus so far studied. The circulatory system is likewise conservative, with a distinct pericardial cavity dorsal to the intestine. The main differences between *N. tamatavica* and *N. nucleus* appear in connection with the digestive and muscular systems. The intestine of *N. nucleus* is shown in Heath (1937, pl. 1, figs. 6, 8); that of *N. tamatavica* (=*rugosa*) in Heath (1937, pl. 2, fig. 13, pl. 3, fig. 23). The more important features of the muscular system of *N. tamatavica* are shown in Heath (1937, pl. 2, fig. 14). From these figures it will be noted that the anatomical differences are relatively slight.

The long-established usage of separating nuculids with crenulate inner ventral margins from those with smooth margins appears to represent a natural and consistent division. *Lamellinucula* is a subgenus related to *Nucula* and other members of the subfamily Nuculinae which possess the crenulate margins. However, a detailed ex-

amination of more than one hundred specimens of *Nucula nucleus* from the coast of the British Isles proves that none of them has the heavy, lamellate concentric sculpture of *Lamellinucula*. The subgenus "*Nuculopsis*" (or "*Nucolopsis*") Woodring, 1925, typified by *Nucula hilli* Woodring, has smooth ventral margins, with concentric

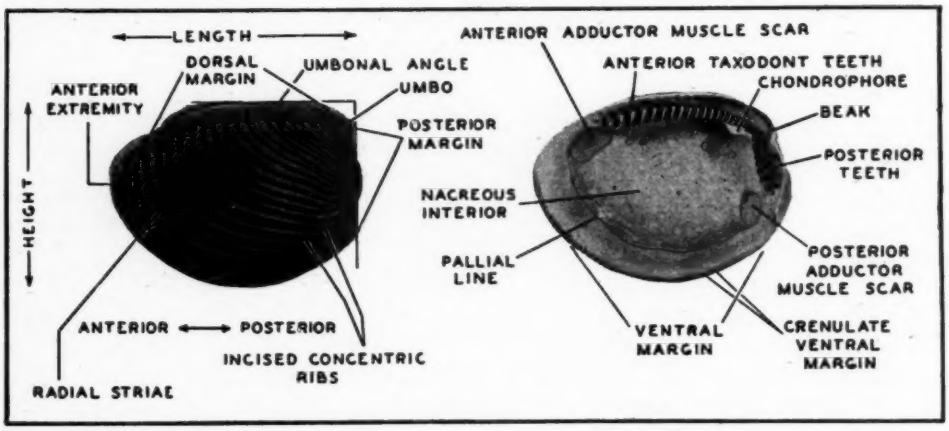

FIG. 1—*Nucula* (*Lamellinucula*) *tamatavica* Odhner, the type of the subgenus. Recent specimen from Madagascar.

1931; *pulchra* Hinds, 1843, and its synonym *sculpturata* Sowerby, 1908; *sagitata* Suter, 1917; *semiornata* d'Orbigny, 1846; *suprastriata* Arnold, 1903; and *tamatavica* Odhner, 1943, the subgenotype.

Further investigation may show that the following species, also originally described as *Nucula*, should be placed in the subgenus

sculpture. *Nuculoma* Cossmann, 1907, typified by *Nucula castor* d'Orbigny, likewise has strong concentric ribs, but it lacks radial striae, has a smooth inner ventral margin, and has conspicuous, tumid umbones. In summary, the chief means of separating specimens of *Lamellinucula* from other nuculid pelecypods is the combination of incised concentric sculpture, weak radial ribs, crenulate inner ventral margin, and from about 4 to 12 posterior teeth.

The following are some of the species originally described as *Nucula* allocated to the subgenus *Lamellinucula: N. ambrosia* Bartrum and Powell, 1928; *duchastelii* Nyst, 1835; *dunedinensis* Finlay, 1928; *exigua* Sowerby, 1833, and its synonym *paytensis* Adams; *gadsdenensis* Mansfield, 1937; *hartvigiana* Dohrn, 1864, and its synonyms *sulcata* Adams, 1856, and *lacunosa* Hutton, 1885; *jeffreysi* Bellardi, 1875; *kalmikensis* Liverowskaja, 1939; *micans* Angas, 1878; *nystana* Le Hon, 1862; *papillifera* Thiele, *Lamellinucula: N. callicredemna* Dall, 1889; *carlottensis* Dall, 1897; *costaeimbricatis* Newton, 1922; *culebrensis* Smith, 1885; *dertonensis* Bellardi, 1875; *hokoensis* Kanehara, 1936; *lamellosa* Venzo, 1939; *orbicella* Olsson, 1922; *regnorum* Wrigley, 1929; *rugulosa* Sowerby, 1833; *tampae* Dall, 1915; *torresi* Smith, 1885; and *zwierzyckii* Oostingh, 1933.

A preliminary analysis of occurrences suggests that the modern representatives of the new subgenus, which is world-wide in distribution, prefer depths ranging from approximately 30 to 120 fathoms, although specimens have been obtained alive, and apparently in their native habitats, in 3 fathoms. The records of the shells in the ocean below 120 fathoms appear valid, but those below 1000 fathoms would seem to be questionable.

For additional bibliographic references and a survey of the family Nuculidae, the reader may find it helpful to consult two of my other papers (Schenck, 1929, 1934).

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MANUSCRIPT RECEIVED JULY 1, 1943.

REQUEST FOR JAPANESE REPRINTS

Certain articles included in the following Japanese publications are urgently needed. They have not been received by any of the libraries consulted, but it is possible that reprints may have been sent to individual American geologists or paleontologists. If any are available, please notify promptly the Chairman, Division of Geology and Geography, National Research Council, 2101 Constitution Avenue, Washington, D.C.

1. Contributions from the Institute of Geology and Paleontology, Tôhoku Imperial University, Sendai, Japan, nos. 1–32, 1921–1939, inclusive. (In Japanese language; not to be confused with Science Reports of this same university.)
2. Bulletin of the Tropical Industrial Institute, Palau, vol. 1, 1938, to date.
3. Jubilee publication in commemoration o Prof. H. Yabe—60th Birthday, vol. 2, 1940.

JOURNAL OF PALEONTOLOGY, VOL. 18, NO. 1, P. 100, PL. 20, JANUARY 1944

A NEW CORAL FROM THE BUDA LIMESTONE (CENOMANIAN) OF TEXAS

JOHN W. WELLS
The Ohio State University, Columbus, Ohio

IN 1933, the writer described 21 species of scleractinian corals from the Buda limestone, including those previously described by Vaughan. The specimen described below was amongst the material studied but was then so completely engaged in matrix that it was put aside as practically hopeless. Recently, however, by the caustic potash method, nearly all the surrounding argillaceous limestone was removed, exposing a fairly well preserved corallum of an undescribed species of *Microsolena*.

Suborder FUNGIIDA
Family MICROSOLENIDAE
Genus MICROSOLENA Lamouroux, 1821
MICROSOLENA WILLIAMSONENSIS
Wells, n. sp.
— Plate 20, figures 1–4

Corallum small, explanate, originally fixed by a small expanded base, roughly circular in outline, upper surface convex, under surface covered by a thin, wrinkled epitheca. Diameter of holotype, *ca.* 50 mm., height, *ca.* 17 mm. Colony formation by intratentacular marginal budding. Corallites distinguished only by scattered centers about 2 mm. apart radially, about 3 mm. concentrically. Centers (calices) flush with general surface. Between centers extend perfectly confluent septo-costae which are undifferentiated from the septa, about 30 in a space of 5 mm. Septa typically microsolenid in structure, equal, fenestrate and regularly perforated. Near the centers the higher-cycle septa unite with those of lower cycles, so that eventually only 8 or 10 reach the columella to which they are attached by synapticulae. Columella a single trabecular pillar.

Occurrence and material.—Upper beds of lower Buda limestone (Cenomanian) at Round Rock, Williamson County, central Texas. One specimen, holotype, U. S. Nat. Mus. 547,426.

Remarks.—This species should be easily recognized by its fine structures, very small close-set centers, and relatively few septa extending to the columella. Another microsolenid occurs in the Buda limestone, *Dimorpharaea manchacaensis* Wells (1933, p. 200, pl. 24, figs. 5–9). This, however, has much coarser structures, more widely spaced centers, proportionally fewer septo-costae, and a different mode of colony formation. In *M. williamsonensis* there is no evidence of the central corallite center and circumoral budding characteristic of *Dimorpharaea*. The only other American Cretaceous species of *Microsolena* is *M. texana* Wells (1932, p. 252, pl. 35, fig. 2; pl. 37, fig. 5) from the lower Glen Rose formation (lower Albian) of central Texas, which has more widely spaced centers, more septa, and coarser structures.

MANUSCRIPT RECEIVED JUNE 4, 1943.

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1

2

3

4

Microsolena williamsonensis Wells, n. sp.

1, Upper surface of corallum, x 1½; *2*, part of upper surface, x 6; *3*, lower surface, showing epitheca with attached tubicolid worm tube, x 6; *4*, transverse section (skeletal material shows white), x 6; holotype.

UNIV. OF MICH.

JOURNAL OF PALEONTOLOGY, VOL. 18, NO. 1, PP. 101–108, 12 TEXT FIGS., JANUARY 1944

NOTES ON FRESH-WATER MOLLUSKS OF IDAHO FORMATION AT HAMMETT, IDAHO[1]

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ABSTRACT—This paper contains a systematic account of 17 species and subspecies of Pliocene fresh-water mollusks from the Idaho formation at Hammett, representing 14 genera in 8 families. Among them, 8 species and 3 genera are herein described as new to science and 2 genera, namely *Orygoceras* and *Angulorbis*, are considered to be of the so-called "Balkan type," on which a preliminary discussion of its morphological resemblance has been included in the introduction.

INTRODUCTION

THROUGH the courtesy of Doctor Leo G. Hertlein of the California Academy of Sciences, I have had the opportunity of examining a collection of fossil fresh-water mollusks from Hammett in Elmore County, southern Idaho. The material was collected by Mr. A. Altha, but no field information other than a precise locality was attached to the collection. Judging by the molluscan species now under consideration, it seems that they are much the same as those found at Castle Creek in Owyhee County Idaho, investigated by the late Dr. William H. Dall (1924) and considered by him to belong to the Idaho formation of Pliocene age. Consequently, it seems reasonable to conclude that these forms from Hammett, recorded in subsequent pages, are of the same age and most probably of the same formation.

The similar elements of molluscan fauna yielded by the present collection, as compared with that of Castle Creek, revive the interesting problem in connection with *Orygoceras* and other genera of what Dr. Dall called the "Balkan type." In addition to those already mentioned by him, *Angulorbis* (n. gen.) is described here, which also bears a remarkable resemblance to a species named "*Carinifex*" *slavonicus* Brusina from the "Neogene" of Slavonia. Judged by the figures, the latter is evidently not a species of *Carinifex* as assigned by Brusina. It is quite possibly a species of *Angulorbis*. So far as the shell features can be traced, as Dr. Dall clearly pointed out, it is hard to differentiate one from another between the the forms of two similar groups discovered in localities so widely separated geographically, however, no explanation has been advanced in either of Dr. Dall's papers on the Castle Creek collection appearing in the year 1924 or subsequently.

Since the present investigation is still in progress, and the small amount of data from one or two localities at hand is so scanty, the present paper attempts to focus its chief interest upon a few points summarized from the facts now known. An adequate treatment of these questions will have to await further discoveries.

First of all, let us examine how far the molluscan forms of the Idaho formation are in harmony with those of the other sites in North America of about the same age. With the exception of the so-called "Balkan type" genera, others such as *Valvata*, *Pyrgulopsis*, *Amnicola*, *Fluminicola*, *Gyraulus*, *Pisidium* and *Sphaerium* are not infrequently recorded from various Pliocene beds, notably the Kettleman Hills of California, reported by Doctor Pilsbry (1934). Moreover, the records show that these genera are still commonly found in the Recent fauna of the Northwestern United States. Consequently, it can not be said that the molluscan remains of the Idaho formation are not in harmony with the fauna of North America in time as well as in space.

On the other hand, our discussion, preliminary though it be on account of the scanty data available, must go to the point

[1] This work was carried on with a grant-in-aid from the Penrose Fund of the Geological Society of America; to the Administrative Officers of the Society, the writer is very grateful. Acknowledgment is also due to Doctor H. A. Pilsbry of the Academy of Natural Sciences of Philadelphia for his valuable suggestions and advice.

in regard to the relationship of these interesting forms, notably of *Orygoceras* and *Angulorbis*, which are contained in the present collection. The forms of both genera are now known only from two distant localities, the Balkan peninsula and Idaho. The specimens of these genera are so much alike in conchological features that it appears impossible to separate them generically. Now then the problem arises: is the striking resemblance due to convergence? or are these forms genetically related?

It has often been maintained that the similarity of forms occurring in very widely separated localities is due to convergent evolution. However, a positive conclusion of this kind is often hard to establish, as the interpretation of the evidence is difficult, as when one tries to restore the ecological conditions, say of a river or lake that existed in Pliocene time. Moreover, comparing the faunal components of both localities where *Orygoceras* and *Angulorbis* have been found, the molluscan elements do not seem to be otherwise quite the same; especially, such genera as *Melanopsis*, *Viviparus*, etc. are conspicuously absent in the Idaho beds and abundantly found in the Balkans. It is true that negative evidence can always be reasoned on the ground of the records being incomplete, etc., but those genera could hardly have escaped detection, being of relatively common occurrence. Consequently, on the basis of the present records available, can it be logically maintained that their difference in elements indicate merely difference in environmental conditions?

Alternatively, whether the resemblance is due to generic relationship is equally a difficult question for the moment; however, a few points may claim our attention. The identification of the congeneric forms of localities geographically remote is difficult to explain, if they could not be proved to be due to convergence. However, such cases are not uncommon in Tertiary as well as in Recent times. The species of *Viviparus* found in Pliocene beds of Yunnan of southwestern China show remarkable resemblance to those forms of the Levantine stage in southeastern Europe. Again, according to Odhner, some of the Eocene fresh-water mollusks found in North China are even considered to be specifically identical with some of the European forms of the same period, and on that basis, he was able to determine the age of the respective formations. His conclusion was later confirmed by evidence of the mammals discovered from the beds of the same locality of the same age.

Without counting numerous groups introduced into one place from another by modern means of communication, etc., further cases can be illustrated in the Recent fauna as well. The heavy types of *Quadrula*, according to Simpson, are recorded from Eastern Asia as well as from North America. The species of *Hawaiia*, which are very commonly found in North America, are also recorded both in the eastern and the western parts of China. *Horatia* is a genus reported from Texas, which is elsewhere known only from Dalmatia, etc.

Furthermore, by studying the molluscan fauna of Recent times, we are also familiar with the fact that the fresh-water forms seem to have a very wide range in distribution. The genera such as *Lymnaea*, *Radix*, *Galba*, *Physa*, *Gyraulus*, *Unio*, *Anodonta*, *Pisidium*, *Sphaerium*, etc. are commonly found almost throughout the Holarctic regions. So that the so-called "Balkan type" genera might also have been for a time widely distributed, and their further discovery in intermediate localities seems highly possible. On the other hand, the occurrence of these genera in distant localities may be a good evidence of migration from one place to the other, but it could also be from a third to both, so that their presence in two localities only should by no means be considered as final.

In summarizing the facts presented above, it seems to be more reasonable to hold the opinion, for the present, that the occurrence of the Balkan genera in southern Idaho, or *vice versa*, may be due to genetic relationship rather than to similar physical conditions of their environment. However, only a comprehensive analysis of the faunas and careful comparison of the bionomics of both localities will yield more reliable information.

In addition to the following systematic account of species, a few groups of larger bivalves had been previously recorded from this formation in various localities of Idaho. They include species of *Unio*, *Anodonta* and *Corbicula*. The presence of these as well as

Goniobasis or its related groups indicate generally that the fossil beds may be of fluviatile origin, but the river might have direct and open connections with a number of lakes of various sizes and of considerable depth. So that the latter will account for the facts that these beds, as exposed in several places, are rather uniform in appearance and of even stratification, and, above all, interstratified with layers of diatomaceous earth of several feet in thickness.

In association with the molluscan remains, numerous fragmentary fish bones have been found, which are not now determinable and for the present can not render useful suggestions in regard to their habitat conditions. However, further collecting will undoubtedly yield better-preserved specimens of other organic remains, so that a more complete study of the bionomics may reveal facts of paleoecological importance.

All the specimens, including the types and figured examples, comprised in this paper are in the possession of the California Academy of Sciences, and they are preserved in the collection of the department of palaeontology with a catalogue number 27272. For economy of space, this will not be repeated in each species.

SYSTEMATIC ACCOUNT OF SPECIES

Family VALVATIDAE

VALVATA HUMERALIS CALIFORNICA Pilsbry

Valvata humeralis californica Pilsbry, 1908, Nautilus, vol. 22, p. 82; 1934. Acad. Nat. Sc. Philadelphia Proc., vol. 86, p. 566, pl. 21, fig. 11, 11a.

There are two well-preserved specimens and a few imperfect ones identical with this subspecies; however, they are slightly smaller. A larger one measures 3.2 mm. in width, 2.5 mm. in altitude, has 3¼ roundly convex whorls.

VALVATA SP. UNDET.

A single specimen in weathered condition, which seems to agree in outline with *V. h. densestriata* Pilsbry; however, the characteristic sharp growth lines are not observable. It has a high spire, flattened apical whorls, and narrow umbilicus. Since the specimen is not in good condition and the elevation of the spire may be considerably variable in the genus, I do not venture to make any specific identification at the present.

Family HYDROBIIDAE

PYRGULOPSIS CARINATA Yen, n. sp.

Figure 1

Shell ovate-turreted in outline, narrowly perforated, the spire slightly higher than the body whorl. Whorls rapidly increasing in height; the apical whorl appears to be round, while subsequent ones are flatly concave and its base scarcely convex. The sculpture consists of a carina from the second whorl and two on the last whorl, the second carina marks the periphery; and the growth lines are strong and distinct. The aperture is oval, having its peristome weakly biangular on the outer margin and well thickened in the inner lip.

Altitude 4.0 mm., width 3.0 mm.; aperture height 2.0 mm., width 1.5 mm.; 4½ whorls.

It differs from *Pyrgulopsis vincta* Pilsbry (1934, p. 15; p. 554, pl. 20, figs. 8, 10–13, 15) by its broader outline and bearing two carinae on the body whorl. It also differs from the recent species *P. nevadensis* (Stearns) by its smaller size and double keels.

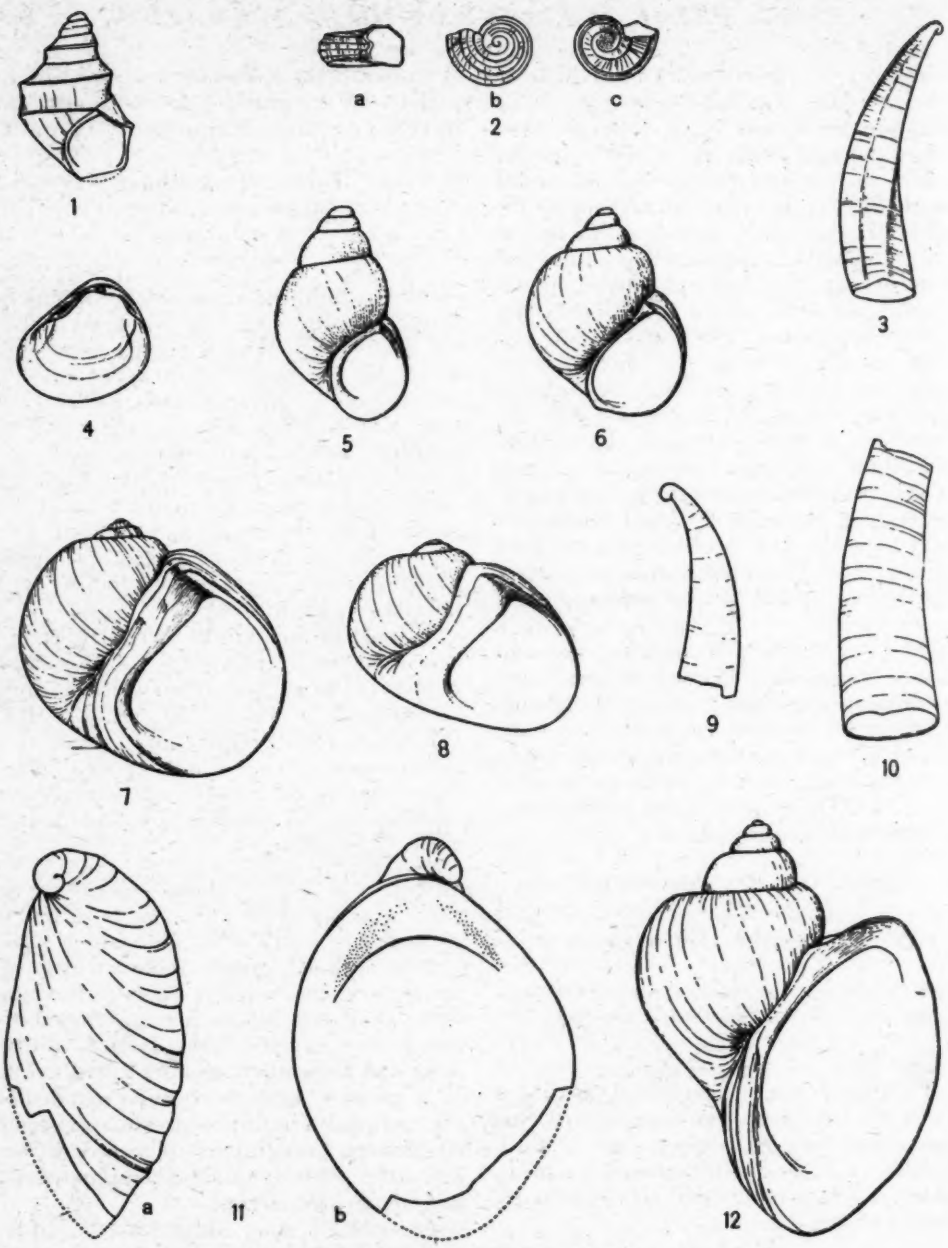
AMNICOLA BITHYNOIDES Yen, n. sp.

Figure 5

Shell narrowly rimate, subovate in form, having its spire slightly higher than the body whorl. The whorls are convex and increase very rapidly. The suture is rather deep, and the growth lines are distinct. The body whorl is gently convex and rounded at the periphery. Aperture ovate, peristome continuous; moderately thickened within and rather strongly calloused on the parietal and columellar margins.

Altitude 5.1 mm., width 3.6 mm.; aperture height 2.5 mm., width 2.0 mm.; four whorls.

The species resembles *A. longinqua* Gould in its general outline; however, it has a larger diameter, with thicker, but not detached, peristome, and is more tapering toward the apex. It differs from *A. puteana* Pilsbry in its higher altitude and narrower width as well as thicker peristome.



EXPLANATION OF FIGURES 1–12

FIG. *1*—*Pyrgulopsis carinata* Yen, n. sp. ×6. (p. 103)
2a–c—*Angulorbis multicarinatus* Yen, n. sp. ×5. (p. 107)
3—*Orygoceras tricarinatum* Yen, n. sp. ×7. (p. 106)
4—*Pisidium exiguum* Yen, n. sp. ×6. (p. 108)
5—*Amnicola bilhnoides* Yen, n. sp. ×6. (p. 103)
6—*Fluminicola weaveri* Yen, n. sp. ×5. (p. 105)
7—*Pilsbryus antiquus* (Gabb). ×2. (p. 105)
8—*Pilsbryus superbus* Yen, n. sp. ×3½. (p. 105)
9, 10—*Orygoceras arcuatum* Dall. ×7. (p. 106)
11a–b—*Payettia dalli* (White). ×4. (p. 106)
12—*Pliopholix idahoensis* Yen, n. sp. ×4. (p. 108)

FLUMINICOLA WEAVERI
Yen, n. sp.
Figure 6

Shell perforately umbilicated, conic-ovate in form. The spire is shorter than the body whorl. The whorls are roundly and strongly convex, increasing rapidly in size and bearing pronounced growth striae. The body whorl is ovately convex, being slightly shouldered near the suture and rounded at the periphery. The aperture is ovate, and its peristome is continuous and thin, having its parietal and columellar margins somewhat reflected as to covering the umbilical crevice.

Dimensions of three individuals of 4½, 4½, and 5 whorls, respectively: Altitude, 5.2, 5.4, 6.0 mm.; width, 3.8, 3.6, 4.0 mm.; height of aperture, 3.5, 3.4, 4.0 mm.; width of aperture, 2.5, 2.4, 2.9 mm.

This species seems to resemble *F. kettlemanensis* Pilsbry in general outline but differs in its smaller size, shorter spire and larger aperture.

The specific name is in honor of Prof. Charles E. Weaver, a well-known authority on Tertiary geology and palaeontology.

Genus PILSBRYUS Yen, n. gen.

Shell imperforate, of thick substance, having a small and depressed spire and dilated body whorl, the latter constitutes almost the entire shell. The whorls are roundly convex, increasing very rapidly; with its early ones more elevated. The sculpture consists of distinct lines or wrinkles of growth marked occasionally by former lip margins, which indicate various resting stages. The suture is deeply impressed by the convex whorls. The body whorl is ventricose, more or less shouldered near the suture, being rounded at periphery and more or less reduced at the base. The aperture is ovate in outline, angular near the suture, where a notch is formed. The peristome is continuous, with its outer lip more or less retreating, and its parietal and columellar margins are strongly and heavily calloused.

Genotype, *Lithasia antiqua* Gabb 1865.

The genus is possibly related to *Lithoglyphus* Hartmann and *Fluminicola* Stimpson; however, it differs from both by its smaller and more depressed spire, its retreating outer lip, and more heavily calloused parietal and columellar margins. In general, the species of *Pilsbryus* are naticoid in outline and of thicker shell substance.

PILSBRYUS ANTIQUUS (Gabb)
Figure 7

Lithasia antiqua Gabb, 1865, Palaeontology of California, vol. 2, p. 13, pl. 2, fig. 23.

This species was described as *Lithasia* and subsequently changed into *Pyrgulopsis* by Hannibal and into *Tryonia* by Wenz. Dall (1924) considered it as a "typical *Lithoglyphus* and the first genuine member of that genus to be reported from the Western Hemisphere." Compared with the genotype of *Lithoglyphus, L. naticoides* (Férussac), which the present species resembles in its general outline, the shell of *Pilsbryus antiquus* is much larger and thicker, and its parietal and columellar margins are much more heavily calloused. One specimen of five whorls measures 19.2 mm. in altitude, 17.2 mm. in width, 16.5 mm. in height of aperture, 12.5 mm. in its width of aperture.

PILSBRYUS SUPERBUS Yen, n. sp.
Figure 8

Shell imperforate, oval in outline, small, having a small and depressed spire and ventricose body whorl, the latter nearly constituting the entire shell. Whorls increasing very rapidly and bearing distinct wrinkles and lines of growth. The body whorl is laterally dilated, rounded at the periphery and reduced at the base. The aperture is large, ovate in outline, having its peristome continuous, angular posteriorly near the suture, where a slight notch is formed. The outer lip margin is thin and retreating at its upper half. The parietal and columellar margins are heavily calloused, and the callosity fills the umbilical region completely. Two specimens of four whorls measure: altitude, 9.6, 9 mm.; width, 8.8, 8.5 mm.; height of aperture, 8.6, 8.0 mm.; width of aperture, 6.6, 5.4 mm.

This species differs from the preceding one by its much smaller size and shorter spire, and its whorls are less convex, the body whorl being more laterally dilated.

Family THIARIDAE

GONIOBASIS TAYLORI (Gabb)

Melania taylori Gabb, 1865, Palaeontology of California, vol. 2, p. 13, pl. 2, fig. 21.

This species and *Pilsbryus antiquus* are the characteristic fossils of the Idaho formation. Its occurrence is common, more individuals being found in young stages. The generic position has never been satisfactorily defined. It was described as a *Melania* and once transferred into *Pachychilus*. It does not seem to belong to either of them. To *Goniobasis* it may be nearly related; however, it does not look like a typical species of that genus. It may represent a distinct subgenus of *Elimia* H. and A. Adams (with E. *aculicarinata* as its type) to be possibly related with the ovate-oblong species of *Goniobasis*. Any definite proposition should be based on the result of a careful revision of the entire group of the forms, which is beyond the scope of the present paper.

Family ANCYLIDAE

PAYETTIA DALLII (White)

Figures 11a, b

Latia dallii White, 1883, U. S. Nat. Mus. Proc., vol. 5, pp. 100, 102, pl. 5, figs. 17–20.

The systematic position of *Payettia* Dall, 1924, seems to be so far rather uncertain. In describing the genus for *Latia dallii* White, Dall assigned it to the Planorbidae. While according to Henderson, 1935, in a private communication to him, Dall had intended to place this genus in the Ancylidae and thought that *Payettia* and *Latia* belong together in a separate group (presumably meaning a separate family or subfamily). If so, it should be placed in the Latiidae, which are so treated in Thiele's "Handbuch" for *Latia*.

The columellar plate of the specimens of *Latia* at hand is quite different from that of *Payettia*. The difference has been well noted by Dall in 1924. On the other hand, this plate in *Amphigyra* Pilsbry and *Payettia* Dall is very similar in type. *Amphigyra* is generally referred to the Ancylidae, with which *Payettia* seems to be more possibly related.

Family LANCIDAE

LANX UNDULATUS (Meek)

Ancylus undulatus Meek, 1870, Acad. Nat. Sci. Philadelphia Proc., vol. 22, p. 57.

A single specimen represents this species, which is rather commonly found in the late Tertiary formations of Nevada and south Idaho. Although imperfect, the specimen can be well identified by its general outline and its undulated sculpture. The apex is well coiled and anterior-central in position.

Family ORYGOCERATIDAE

ORYGOCERAS ARCUATUM Dall

Figures, 9, 10

Orygoceras arcuatum Dall, 1924, U. S. Geol. Survey Prof. Paper 132-G, p. 113, pl. 26, fig. 5.

Numerous specimens in the lot indicate its common occurrence in the formation. However, they are mostly represented by their apical parts, and others by the posterior part of the tube. The species is characterized by its slightly coiled apex, arcuate and weakly striated, otherwise smooth on its surface.

ORYGOCERAS TRICARINATUM

Yen, n. sp.

Figure 3

Shell apparently dextral, minute, nearly straight, with its smooth one-half apical whorl coiled. Immediately below the initial whorl, three carinae appear, which continue as far as to the anterior end of the tube, two marking the lateral sides and one on the dorsal surface, which is otherwise roundly convex. The basal or the central surface of the tube is flatly concave and is well defined by the two edgewise carinae. In the central part of the surface there are longitudinal lines or wrinkles. The lines of growth are very distinct and sometimes quite pronounced. The aperture is subtriangular in form, being determined by the three carinae over the surface of the tube. Its peristome is simple and thin.

Length, 5.5 mm.; diameter 1.2 mm.

This species resembles very closely *O. tropidophorum* Brusina from Bosina, but it differs by its much larger size and less strong carinae.

This genus is so far known only in the fossil state from the Balkan States and south Idaho. Although they are so widely separated in geography, no morphological difference of generic importance can be traced.

Family PLANORBIDAE
GYRAULUS SP. UNDET.

A single specimen in a poor state of preservation represents this common fresh-water genus. The specific identity is not determinable, but its planorboid outline and rapidly increasing whorls indicate sufficiently the features of *Gyraulus*.

Genus ANGULORBIS
Yen, n. gen.

Shell planorboid, minute, having a slightly sunken spire and perspective umbilicus. The basal surface is more concave than the apical view. The whorls increase very rapidly in size. The protoconch or nuclear whorl is smooth, while the subsequent ones bear characteristic spiral carinae and strong growth lines. The aperture is large and angular in form, peristome simple, having its inner margin moderately thickened.

Genotype, *Angulorbis multicarinatus* Yen.

The genus here under consideration is possibly related to *Gyraulus* Agassiz but differs in its sculpture. It evidently represents a highly specialized branch of Planorbidae already extinct; however, it might have a wide range of distribution in Pliocene time. "*Carinifex*" *slavonicus* Brusina, 1897, which was described from the "Neogene" of Slavonia, seems to belong to this genus, and their morphological resemblance strongly suggest their congeneric relationship despite their wide separation in geography.

ANGULORBIS MULTICARINATUS
Yen, n. sp.
Figures 2a–c

Shell minute, of thin substance, perspectively and widely umbilicated. Whorls increasing rapidly in size, its surface is convex above the periphery and concave on its base. The sculpture consists of spiral carinae, which are decussated by strong lines of growth. The carinae are nine in number on the body whorl, one along the periphery, five above and three below. The peripheral one is comparatively weak, the two immediately below mark the edge of the base while the lowermost one defines the umbilical region. Aperture angular in form, which is determined by strong carinae on the body whorl. The peristome is simple, with its inner margin well thickened.

Altitude, 1.2 mm.; width, 2.3 mm.; aperture height, 1.0 mm.; aperture width, 1.0 mm.; three whorls.

This species resembles closely *Angulorbis slavonicus* (Brusina), which was originally described as a species of *Carinifex* from Slavonia, and which is evidently not a species of that genus at all.

Among the forms described from this hemisphere, the species may possibly be related to "*Gyraulus*" *monocarinatus* Chamberlin and Berry (1933, p. 27, pl. 5, figs. 7–8), from a Pliocene deposit at Collinston, Utah, and "*Menetus*" *planumatoides* Henderson and Rodeck (1934, p. 268, pl. 37, fig. 4), from a Pliocene deposit of eastern Oregon. Judging by the descriptions and the figures, these two species seem to be congeneric, and they differ from the present species by its roundly convex base and simple sculpture.

Genus PLIOPHOLYX Yen, n. gen.

Shell rimate, subglobose in outline, of thick substance, with a more or less elevated spire and ventricose body whorl. Whorls are slightly shouldered, with a deeply impressed suture. The sculpture consists of lines and wrinkles of growth. The aperture is ovate in form, having a slight notch near the suture and a short anterior spur below. The peristome is continuous and simple, thin and more or less expanded, lower part of the outer margin slightly retreating, the parietal wall is rather thin but well defined, and the columellar margin is well thickened and nearly straight.

Genotype, *Pliopholyx idahoensis* Yen.

With a superficial resemblance to some species of *Radix*, *Pliopholyx* can be readily distinguished by its shouldered whorls and deeply impressed suture as well as, however short, the posterior and anterior notches of the aperture. It is difficult to ascertain its relation with other genera on record, and its shell features seem to suggest that it is possibly related to *Parapholyx* Hanna, a genus recorded both in fossil and living state in the western United States. The elevation of the spire is generally variable as that in other cases, but it is never very

much depressed. The aperture features also remind one of some genera of Planorbidae.

PLIOPHOLYX IDAHOENSIS Yen, n. sp.
Figure 12

Shell rimately umbilicated, subglobose, of thick substance, having an elevated spire and dilated body whorl. Whorls rapidly increasing, the first two being roundly convex and the last three being shouldered near the suture. The body whorl is more than twice the height of the spire and is somewhat laterally ventricose and roundly convex at the periphery. The sculpture consists of distinct lines of growth. The aperture is ovate in outline, having a slight notch produced posteriorly near the suture and anteriorly close to the columellar margin. The peristome is continuous, more or less expanded, having its outer margin slightly retreating at its lower part and its parietal and columellar walls are well thickened.

The dimensions of three individuals of 5½, 5¼, and 5 whorls are, respectively: altitude, 13.2, 14.0, 12.0 mm.; width, 11.0, 10.6, 9.8 mm.; height of aperture, 10.8, 11.4, 9.8 mm.; width of aperture, 7.2, 6.5, 6.0 mm.

This species is well characterized by its thick shell substance, shouldered whorls, thick parietal and columellar margins and short posterior and anterior notches.

Family SPHAERIIDAE
SPHAERIUM IDAHOENSE Meek

Sphaerium? idahoense Meek, 1870, Acad. Nat. Sc. Philadelphia Proc., vol. 22, p. 57.

This species seems to be quite commonly found throughout this formation; however, it was originally described from Hot Spring Mountains at Fossil Hill, and Dall recorded it from Castle Creek.

PISIDIUM EXIGUUM Yen, n. sp.
Figure 4

Shell thin in substance, of small size, and trigonal in outline.

The beak is obtuse, low, and posterior-central in position. The hinge is arched, with its anterior margin nearly straight and posterior margin short and well curved. The right valve has two anterior laterals and two posterior ones, and the space between each pair is narrow and deep, which receives the single high, pointed laterals on the left valve. The cardinal on the right valve is elongate, slightly curved, with its posterior end heavier, while the two on the left valve are gently curved.

Length, 3.5 mm.; height, 3.2 mm. (type, right valve).

This species differs from the widely distributed living *P. compressum* Prime in its smaller size, less robust anterior laterals and longer cardinal; it also differs from *P. c. praecompressum* Pilsbry in its less strong laterals and less curved cardinals.

It resembles in general outline *P. curvatum* Hanna, described from the upper Miocene of Sonoma County, California; however, it is readily recognized from that by its obtuse beak, lower laterals and straighter cardinals.

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